ISASI FORUM
"Air Safety Through Investigation"

JULY–SEPTEMBER 2011

NTSB Chair Deborah Hersman Accepts ISASI Honorary Membership

Certificate of Membership

Deborah A. P. Hersman
Is an Honorary Member of
The International Society of Air Safety Investigators
which is dedicated to
"promote that part of the aeronautical endeavor
wherein lies the moral obligation of the Air Safety Investigator to
the public"

April 14, 2011
HO0008
Frank Del Gandio, President

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National Transportation Safety Board Chairman Deborah A.P. Hersman accepts honorary membership in the International Society of Air Safety Investigators from ISASI President Frank Del Gandio. Shown is the certificate plaque presented to Chairman Hersman. Photo: Esperison Martinez, *ISASI Forum* Editor

ISASI FORUM
"Air Safety Through Investigation"

Volume 44, Number 3

Publisher Frank Del Gandio
Editorial Advisor Richard B. Stone
Editor Esperison Martinez
Design Editor William A. Ford
Associate Editor Susan Fager
Annual Report Editor Paul Mayes

ISASI Forum (ISSN 1088-8128) is published quarterly by International Society of Air Safety Investigators. Opinions expressed by authors do not necessarily represent official ISASI position or policy.

Editorial Offices: Park Center, 107 East Holly Avenue, Suite 11, Sterling, VA 20164-5405. Telephone (703) 430-9668. Fax (703) 430-4970. E-mail address isasi@erols.com; for editor, espmart@comcast.net. Internet website: www.isasi.org. ISASI Forum is not responsible for unsolicited manuscripts, photographs, or other materials. Unsolicited materials will be returned only if submitted with a self-addressed, stamped envelope. *ISASI Forum* reserves the right to reject, delete, summarize, or edit for space considerations any submitted article. To facilitate editorial production processes, American-English spelling of words will be used.

Publisher's Editorial Profile: *ISASI Forum* is printed in the United States and published for professional air safety investigators who are members of the International Society of Air Safety Investigators. Editorial content emphasizes accident investigation findings, investigative techniques and experiences, regulatory issues, industry accident prevention developments, and ISASI and member involvement and information.

Subscriptions: Subscription to members is provided as a portion of dues. Rate for nonmembers (Domestic and Canada)is US$28; Rate for nonmember international is US$30. Rate for all libraries and schools is US$24. For subscription information, call (703) 430-9668. Additional or replacement *ISASI Forum* issues: Domestic and Canada US$4; international member US$4; domestic and Canada nonmember US$6; and international nonmember US$8.

AIR SAFETY INVESTIGATORS
INCORPORATED AUGUST 31, 1964

PRESIDENT'S VIEW

NTSB Chair Hersman Accepts ISASI Honorary Membership

By Frank Del Gandio, ISASI President

On April 14, I was privileged to present and have U.S. National Transportation Safety Board Chairman Deborah A.P. Hersman accept an honorary membership in our Society. This is only the eighth honorary membership awarded in 47 years. It is our first since 2001, when Congressman James L. Oberstar was presented the award.

The significance of this award to our society is embedded in ISASI's creation in 1964 as envisioned by Joseph O. Fluett and Truman (Lucky) Finch, Society forefathers. Our first set of by-laws established that "It is the policy of the Society of Air Safety Investigators to offer honorary memberships to those persons recommended…who have made outstanding contributions to air safety."

Our presentation was made in the chairman's 6th floor office of NTSB headquarters in Washington, D.C., which offers a view of Ronald Reagan Washington National Airport's expansive airspace, which is continuously filled with airliners coming and going. It is against this backdrop of our aviation world that I took great pleasure in awarding the title of honorary member in the International Society of Air Safety Investigators. Hersman is truly one of us, as demonstrated by her tenacious and ever-persistent approach to safety.

Many persons may not recall that for five years prior to accepting the chairmanship of the NTSB on July 28, 2009, she served as a member of the NTSB. In that time, she oversaw 17 major transportation accident investigations. These events covered all modes of transportation: airliners, emergency medical service and sightseeing helicopters, business jets, private aircraft, light rail trains, freight trains, container ships, recreational boats, school buses, and motor coaches. Since being sworn into office, she has become the public face of the agency's investigators and investigations.

In addressing our Society's annual seminar in 2009, just seven weeks after being sworn into office, Hersman spoke of her self-imposed challenge to raise the bar of three attributes she believed were critical to the NTSB's mission and work: transparency, accountability, and cooperation. It is a mark of her fidelity that she has been successful in leading the agency to meet that challenge, which benefits investigators everywhere.

ISASI Honorary Members

HO0001—Alan S. Boyd
June 1, 1965 (deceased)
HO0002—Najeed E. Halaby
June 1, 1965 (deceased)
HO0003—Charles S. Murphy
April 1968 (deceased)
HO0004—Mike A.S. Monroney
May 14, 1968 (deceased)
HO0005—Walter Tye
Jan. 1, 1969 (deceased)
HO0006—Joseph J. O'Connell, Jr.
1969 (deceased)
HO0007—James L. Oberstar
April 27, 2001
HO0008—Deborah A.P. Hersman
April 14, 2011

We have seen an elevation of the agency's transparency by a more prompt release of factual investigation information to the public both through the news media and through the opening of agency dockets to the public via the NTSB website. Board meetings and hearings are now not only open to the public, but are also webcast, so anyone can listen and watch. In terms of accountability, the NTSB has become stronger, more efficient, and more nimble in both its domestic and international roles. And while the "cooperation challenge" has brought closer coordination and support between the agency and accident investigations authorities from other countries, it has also enhanced existing systems of keeping families of accident victims informed and strengthened the agency's "listening" role.

E. MARTINEZ

President Del Gandio presents Chairman Hersman her certificate of honorary membership.

Chairman Hersman's contributions to aviation safety and her support of ISASI have been phenomenal. Her ability to deal with a myriad of issues and tragedies, coupled with her tenacious approach to safety, identifies her as a true representative of the traveling public. She more than fulfills the lasting code etched on her certificate of membership, which reads: "Deborah A.P. Hersman is an honorary member of ISASI, which is dedicated to promote that part of the aeronautical endeavor wherein lies the moral obligation of the air safety investigator to the public."

In presenting the certificate, I said: "You are the most 'safety motivated' person I've seen in my 30-years of accident investigation. Your approach to safety mirrors the aims of our Society; therefore, I am proud to make you an honorary member of the International Society of Air Safety Investigators." ◆

V.P.'S CORNER

Reporting on My Washington Visit to the International Council

By Paul Mayes, ISASI Vice President

The main activity since the previous issue of *ISASI Forum* was my travel to Washington for the spring ISASI International Council Meeting (ICM) on May 6. I also took the opportunity to visit ISASI's office in Sterling, Va., and spend time with Ann Schull, our office manager, and Tom McCarthy, ISASI's treasurer. I encourage members to call on Ann in the office if you are in the Sterling area. The office is the center of ISASI operations, and I am sure Ann would be very pleased to meet any of our members.

All Council members attended the ICM except Peter Williams from NZSASI, who participated by telephone, and International Councillor Caj Frostal, who was not available. The national societies agreed to fund the costs for their representatives' travel to this meeting on this occasion, which ISASI had declined to do because of its current financial position.

The day before the meeting, the Executive met and concentrated discussions on ISASI's financial situation. The financial reports from Treasurer Tom McCarthy and President Frank Del Gandio were discussed at length, and the Executive was satisfied that we had a complete and accurate understanding of the current financial situation. The conclusion was that ISASI is very sound financially with extensive assets, but we will concentrate on building our cash reserves in the next 2 years.

The ICM lasted all day (about 8 hours), and at times there were vigorous discussions. Frank pointed out that meeting ISASI International Council members' travel expenses to the ICM is expensive (approximately $15,000) and asked once again whether we should be continuing with two face-to-face meetings per year or cut back to one. There was divided opinion, but eventually the Council decided that two face-to-face meetings should be the norm, although on occasion, one may need to be a teleconference. Frank mentioned that the number of ISASI Fellows remains at a low level and encouraged those who feel that they meet the eligibility criteria to consider applying. Costs are $50 on application and $50 if and when accepted.

I reported on a review I had commenced on how to build our membership and the preliminary suggestions on how to recruit and maintain members. There was considerable discussion about paying dues online directly to ISASI, but national societies were largely against this. They normally collect dues on behalf of ISASI and forward a consolidated list and payment to Ann. This allows the national societies to maintain direct communication with their membership and in some cases assist members by subsidizing part of ISASI dues. The Council decided not to make changes at this time.

In an effort to retain members, one suggestion was to reduce the dues for members who had reached retirement age and were no longer employed. For retired members, a 50% reduction in annual dues could be considered. There was mixed reaction to the proposal, including concern that there may be practical difficulties in deciding when a member has actually retired. I raised some ideas to reduce our costs, which included electronically distributing *ISASI Forum* and reducing the *Proceedings* to an electronic copy. *Forum* currently costs about $50,000 to produce and distribute. But there was little support from the members for any significant changes. Reducing the quantity of magazines printed for each edition would not significantly reduce the overall cost, and the president was against reducing the number of editions from four to three per year.

ISASI website home page (www.isasi.org)

I raised some ideas for increasing communications. Frank agreed to produce a newsletter on a regular basis. There are several ideas for improving the website and making it more friendly and informative. With 1,430 members in 67 different countries around the world, the website is our shop front and should provide current information and news. I believe we need to make significant changes so that it is can be the link with all our members.

These will be some of several ideas to be canvassed from members in a membership survey I will be developing and sending out in the next few months. We want to get your ideas and feedback on the Society so that we can determine ways we can move forward. We need to utilize the latest technology and ideas for communications and improve our services to members. ◆

Using Commercial Satellite Imagery in Aircraft Accident Investigation

The authors evaluate the current state of the art focusing on the needs and priorities of an accident investigation and reporting on live trials conducted in Cyprus in 2009.

By Dr. Matthew Greaves (AO7700) and Professor Graham Braithwaite (MO3644), Cranfield Safety and Accident Investigation Centre, Cranfield University, UK

(This article is adapted, with permission, from the authors' paper entitled The Use of Commercial Satellite Imagery in Aircraft Accident Investigation *presented at the ISASI 2010 seminar held in Sapporo, Japan, Sept. 6–9, 2010, which carried the theme "Investigating ASIA in Mind—Accurate, Speedy, Independent, and Authentic." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org.—Editor)*

In the majority of aircraft accidents, the wreckage is easily located and is accessible to investigators; however, there are notable exceptions. The loss of Air France Flight 447 over the Atlantic Ocean in 2009 and Adam Air Flight 574, which crashed near Indonesia in 2007, show the difficulty that can be experienced in locating aircraft wreckage. Similarly, the RAF Nimrod, which crashed in Afghanistan in 2006, and UTA Flight 772, which broke up over the Sahara Desert in 1989, both show that wreckage can be difficult or even impossible to access due to either political or geographical constraints.

For these reasons, there has been an increasing interest in the use of general aerial imagery for the location and subsequent analysis of aircraft accidents. In more populated areas, this may come from police, air ambulance, or even news helicopters; but again, this will be absent in more remote regions. Some agencies and organizations may have arrangements that allow access to imagery from military satellites, which may have different capabilities than commercial satellites. Following the loss of Flight 447, a request was made for the U.S. government to use satellite technology to assist in the search for wreckage. However, there are often issues surrounding the priority of acquiring this imagery and its subsequent access and use in the civilian domain. As a result, attention has turned to the use of commercial satellite imagery for accident location and investigation.

Commercial satellite imaging

The availability and use of commercial satellite imagery has grown markedly in recent years with no better demonstrator than the ubiquitous *Google Earth*. However, acquiring this imagery on demand is not cheap, and therefore it is useful for investigators to know what can potentially be achieved by this technology. For example, it would be helpful to know whether, say, a flight data recorder can be identified by a particular satellite before spending many thousands of pounds acquiring the image to order. While the published specifications of the imaging satellite can provide some of this information, they are not the whole picture.

There is a wide range of satellites offering images in the visible spectrum, all with different resolutions and characteristics. Table 1 shows some of the higher resolution satellites and the best resolution available from each. This indicates the smallest dimension that can be resolved and hence a lower number is better. Resolutions are shown for both panchromatic images (black and white) and multispectral (color and other bands). Clearly, the panchromatic resolutions are much greater than the multispectral. One useful concept when dealing with satellite imagery is that of ground sample distance (GSD), which is the size of area on the ground represented as a pixel at nadir (i.e., overhead). As the viewing angle changes from directly overhead, i.e., increasing off-nadir angle (ONA), the available resolution reduces.

Table 1. Available Resolutions of Commercial Satellites
**Subject to restrictions, see below.*

Satellite	Panchromatic (m)	Multispectral (m)
OrbView-3	1	4
IKONOS	0.82	4
EROS-B	0.7	-
QuickBird	0.61	2.44
WorldView-1	0.5	-
WorldView-2	0.46*	1.84*
GeoEye-1	0.41*	1.64*

While satellite resolutions continue to improve, the distribution and use of imagery from U.S.-owned satellites at better than 0.50 m GSD panchromatic and 2.0 m GSD multispectral are subject to prior approval by the U.S. government. Without this approval, images at resolutions better than 0.5 m will be resampled to give 0.5 m resolution. While this approval may be granted in the case of accident investigation and resolutions will continue to improve, it is at least feasible that resolutions better than those currently offered will not be available in the near future.

One useful technique aimed at maxi-

Figure 1a. Handheld image from helicopter of the grid.

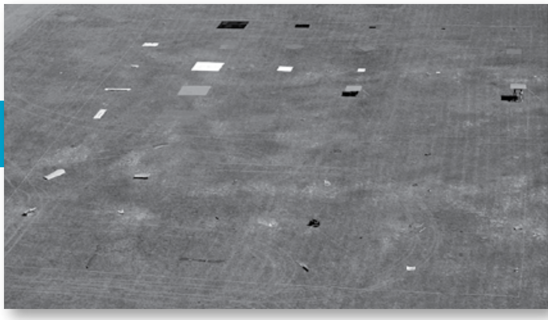

Table 2. Available Resolutions of Commercial Radar Satellites

Satellite	Resolution (m)
RADARSAT-2	3
COSMO-SkyMed	1
TerraSAR-X	1

mizing the information available from electro-optical (EO) imagery is that of pan-sharpening, which can often be specified when requesting the imagery. This involves fusing the color information from a multispectral image with the geometric information from the panchromatic image, essentially yielding a high-resolution color image.

Commensurate with this growth in EO satellites has been an increase in the availability of commercial radar imagery, albeit at slightly lower resolutions. Table 2 shows three of the commercial radar satellites available and their associated resolutions. EO satellites are unable to image through thick cloud, whereas radar does not suffer from the same limitation. This is particularly relevant when considering that poor weather is a factor in many accidents.

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Graham Braithwaite *is head of the Department of Air Transport at Cranfield University, UK. He was appointed director of the Safety and Accident Investigation Centre in 2003 and awarded a chair in safety and accident investigation in 2006. Prior to this, he worked as a lecturer at the University of New South Wales, Sydney. Graham holds a Ph.D. in aviation safety management from Loughborough University, and his research has focused on issues of safety, culture, and investigator training.*

In general when obtaining satellite imagery of a particular location, it is possible either to purchase a pre-existing "library" image or to task the satellite to acquire a new image. Clearly, while library imagery is useful for planning, recovery, visualisation, etc., it offers little to support the process of investigating the accident. Therefore, if up-to-date imagery of the accident site is required, it will be necessary to task the satellite to acquire specific imagery. The speed with which this can be done depends on a number of factors including budget, priority, and satellite orbit. However, as a general guideline, the minimum time it would take to task a specific image, from point of request to having the image, would generally be between 1 and 2 days.

Imaging satellites are scientific instruments with a wide range of parameters that need to be specified before acquiring an image. An analogy can be drawn with SLR cameras where there are many modes and settings, some of which will drastically affect the outcome of the image. While it is beyond the scope of this article to discuss the specifics of acquiring an image, parameters that can be adjusted include file type, imaging mode (related to imaged area and resolution), datum and projection, post-processing, dynamic range, etc. It should be noted that just like the zoom lens on a camera, most satellites can image a range of areas (e.g., 5 km x 5 km, 10 km x 10 km, etc.) but that an increase in area will often lead to a reduction in resolution.

Once an image has been acquired, it is usually delivered as a digital file. Dependent upon the size of the imaged area, the file size involved can be significant, e.g., 1 GB for a 10 km x 10 km image, which has implications with respect to file handling. The majority of current handheld devices will not deal with a file this size. An additional complication arises from the file format. While it is often possible to specify the delivered format, the default format can be, say, the National Imagery Transmission Format (NITF) rather than the more common TIFF or JPEG. This means that the processing chain should also be considered when acquiring imagery as specialist software may be required to view the image. In some cases, further post-processing is required before anything resembling an image is produced.

These points are not raised to discourage the investigator, but rather to highlight the need to prepare for the possibility of a need to use imagery in the future. Attempting to understand the different satellite parameters should not be done while searching for a lost aircraft. Therefore, it may be appropriate for a representative to engage with a satellite imagery provider to establish a "standard" set of parameters and a processing workflow before it is needed.

Trial configuration

To assess the potential utility of satellite imagery in aircraft accident investigation, a trial was conducted in which known targets were set out and imaged. The trial was conducted in collaboration with the UK Ministry of Defence (MOD), the UK Air Accidents Investigation Branch (AAIB), and the Defence Science and Technology Laboratory (DSTL). Cyprus was chosen as a location for the trial due to the generally clear skies and the availability of open space.

Three test sites were set up: the first used accident-damaged aircraft components (metallic, carbon fiber, and mixed materials) in representative terrain, and the second used a helicopter door and tail boom floating at sea. The third site consisted of a grid of objects of various sizes and materials including metal squares

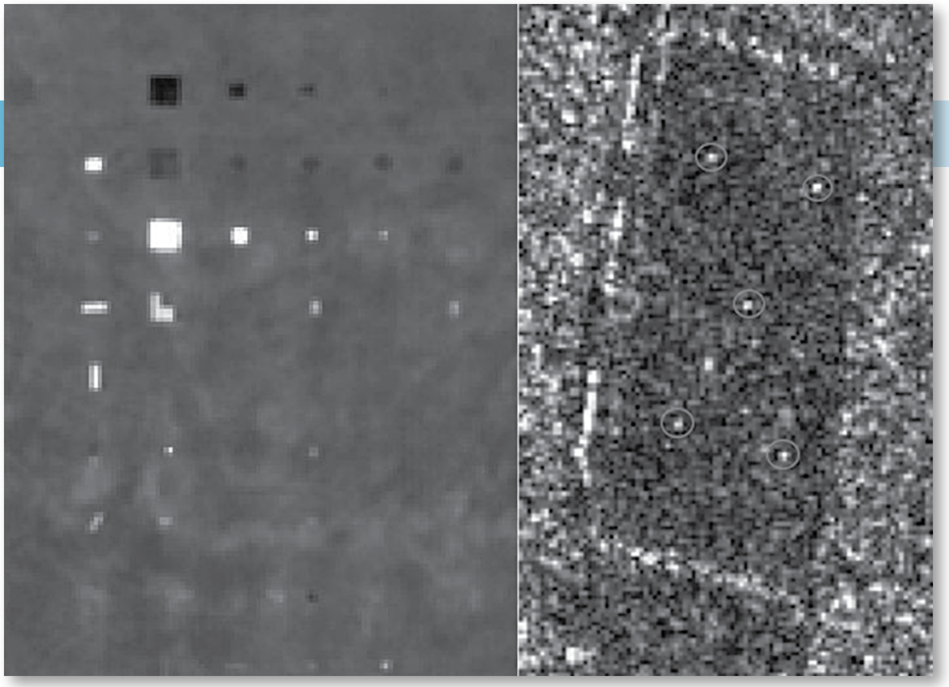


Figure 1b. Commercial satellite image (left). Figure 1c. Radar image of the grid (radar reflectors circled) (right).

ranging from 0.5 m x 0.5 m to 4 m x 4 m and real wreckage, all for use as a "testcard" for the satellite. These sites offered an array of problems at the more challenging end of wreckage location and plotting. Clearly, finding an intact 50 m fuselage will be easier than a 4 m x 4 m square panel. All three sites were also surveyed by the Joint Aircraft Recovery and Transportation Squadron (JARTS) using differential GPS mapping.

Two images were acquired of the site; an electro-optical image from the QuickBird satellite and a radar image from the TerraSAR-X synthetic aperture radar satellite (courtesy of infoterra GmbH).

The QuickBird image was of a 10 km x 10 km area, taken with a 0.6 m (panchromatic) and 2.4 m (multispectral) ground sample distance at an average off-nadir angle of 3°. The file was supplied in NITF 2.1 format with a file size of 960 MB. The image was requested at "assured" tasking level for a time window of Aug. 17–21, 2009, and was acquired on Monday, August 17, at 08:42 GMT. (This is relevant because painting of the target was completed at approximately 10:00 GMT; a comparison of Figures 1a and 1b shows that the 4 m x 4 m orange square is only three-quarters completed and the other two "orange" squares are unpainted and not raised!) The file was viewed using GeoGenesis Lite, a free NITF viewer from IAVO. The commercial cost of tasking this image, given the assured tasking level and relatively narrow acquisition window, would be in the region of £10,000.

The TerraSAR-X image was acquired of a 10 km x 10 km area in "spotlight" mode giving a 1 m GSD. However, by the nature of its operation, the preferred range of acquisition angles for this satellite is 20° to 55° with the trial image being acquired at 48°. This acquisition angle results in a reduction in resolution to approximately 1.5 m. The file was delivered as a complex SAR image and was approximately 220 MB in size. Analysis was performed using Radar Tools, an open source application. The commercial cost of tasking this image would be in the region of £7,000.

Figures 1a–3a show handheld imagery of the three sites taken from a helicopter, corresponding pan-sharpened electro-optical images extracted from the QuickBird image, and two images extracted from the TerraSAR-X image.

Analysis

Each of the items in the grid was analyzed for interpretability by examining the image and deciding whether it was distinct from the background, i.e., whether there was "something there." No attempt was made to interpret the detail of the item.

Of the 50 targets that were in the grid, 20 were clearly visible, 7 were marginal, and 23 were undetectable. The clearly visible targets included a 2 m x 2 m black square, a 1 m x 1 m white square, a tail panel, and a bulkhead (each 2 m x 1 m approximately). The marginal targets included a 1 m x 1 m black square, a 0.5 m x 0.5 m white square, a canopy section, and a pair of seats. Those targets that were deemed undetectable included a 0.5 m x 0.5 m black square, a 4 m x 4 m Perspex square, a helicopter rotor blade, and a flight data recorder.

These results highlight the other factors that impinge upon the interpretability of an image. While the panchromatic GSD of 0.6 m gives an indication of the results that might be available, the results are also heavily affected by other factors such as the surrounding area, object color, viewing geometry, etc. It is interesting to note, for example, that the 2 m x 2 m black square is clearly visible occupying approximately 4 pixels by 4 pixels, but also is the 1 m x 1 m white square occupying 2 pixels by 2 pixels, while the 1 m x 1 m black square is considered marginal. Because of the colors present in the surrounding area, a white pixel is much higher contrast than a black pixel, making it more prominent.

In order to test the geolocational accuracy of the satellite image, 20 items were chosen from the grid, the location of the item's center was estimated, and the coordinates were noted, as displayed by the software based on the geographical information embedded within the image. These coordinates were then compared with the surveyed data.

Comparing the coordinates for absolute accuracy (i.e., comparing merely the precise coordinates), the average error was 10.25 m for the easting and 3.56 m for the northing with a maximum error of 10.80 m and 3.7 5 m, respectively. Assessing the relative accuracy (i.e., the distance between items), the average error was 0.20 m for the easting and 0.08 m for the northing with a maximum error of 1.05 m and 0.23 m, respectively.

Given the distances involved from sensor to object and the potential errors due to pixellation and center estimation, these accuracies are exceptional. Notwithstanding the issues of interpretability above, a typical maximum error of 20 cm would be deemed more than accurate enough for wreckage plotting from a distance.

One technique that is often referred to in imagery analysis is that of change

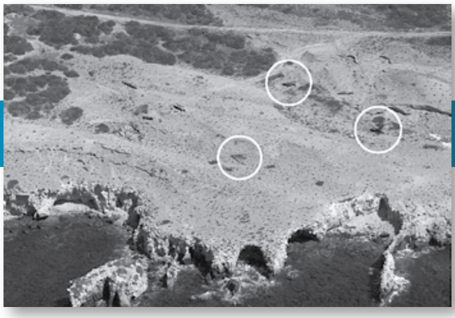


Figure 2a. Handheld image from helicopter of the Harrier site. (Both wings and tailplane circled.)

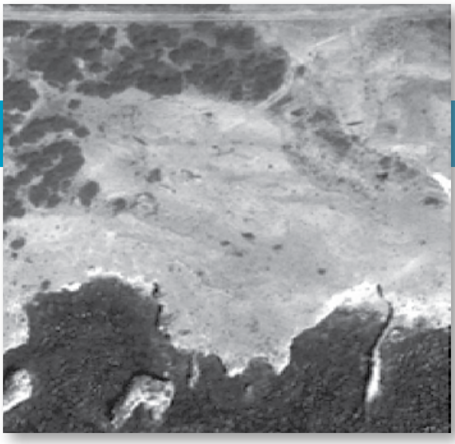


Figure 2b. Commercial satellite image of the Harrier site.

detection. This involves taking a "before" image and comparing it to the "after" image in order to highlight any differences. This can either be done manually or in software. The manual approach may be as simple as viewing the two images on the screen simultaneously and moving them around in a synchronized way looking for differences or anomalies. While this method is labor intensive, it can be extremely effective.

The software approach uses algorithms to compare the before and after image. However, this technique works most effectively when using "matched" images, i.e., images taken from the same sensor, at the same resolution, with the same geometry with only differences of interest present.

Clearly, since the next accident location is unknown, the likelihood of matched imagery being available is low. Therefore, automated change detection was attempted on the QuickBird image of the grid, with an image from the GeoEye satellite providing the reference from which to detect change. While it would be possible to adjust the detection parameters in order to highlight the areas of known change, the point of using this technology is to detect change where it is unknown. Therefore, the change detection was performed using standard parameters.

A piece of software called Matisse, written by DSTL, was used in an attempt to detect change. After performing the change detection, one of the panels in the grid was highlighted by the software as the most prominent change in an area of 700 m x 700 m around the grid. Expanding this to a 4 km x 3 km area resulted in the software highlighting the same panel as being one of the 50 most prominent changes in the scene.

Clearly, this technique will not be used as a totally automated process, but rather as a way of highlighting possible areas of interest to an imagery analyst. Therefore, given the results above, it is feasible that an analyst may be able to process the changes highlighted in, say, a 10 km x 10 km scene in a day—although as the algorithm ranks possible detections, the more highly ranked a find is, the more likely it will be found by the analyst early in the process.

Examination of the radar image of the grid highlights some of the difficulties of working with radar. The five radar reflectors (laid out like the face of a die) are visible and circled in Figure 1c, as are some of the other components including the tail plane. However, the resolution is such that each item occupies no more than one pixel in size. This makes it very difficult to interpret the image.

Figures 2a and 2b show the Harrier site. While the bright blue parachute in the top left-hand corner of the image is clearly visible, comparison of the two images clearly highlights the difficulties in distinguishing the wreckage from the surrounding scrubland. The wreckage visible in this image includes both wings, the rear fuselage, and both drop tanks from a Harrier. There are also many other smaller parts in the images, such as pipes and a nose gear leg, but these are only visible from the helicopter image when zoomed and are not visible on the satellite image.

Figures 3a and 3b show the helicopter and satellite image of the sea site. The handheld image shows a helicopter tailboom floating in the water and a red door on the beach. However, it is not possible to distinguish any of

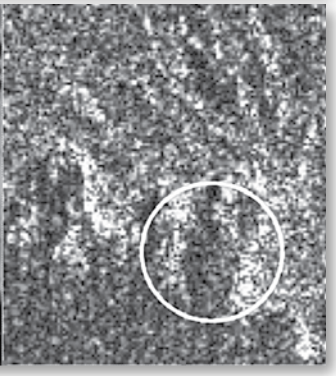


Figure 3a. Handheld image from helicopter of the sea site (left). Figure 3b. Commercial satellite image of the sea site (below left). Figure 3c. Radar image of the Harrier and sea sites (below right, sea site circled).

Figure 4a. Wreckage trail and surrounding area.

Figure 4b. Wreckage trail enlarged.

the wreckage from the surrounding land or the sea. Similarly, the resolution offered by the radar image in Figure 3c, coupled with the noise and returns from the surrounding area, make it impossible to identify any wreckage and difficult to even identify the local geography.

Practical example

On April 10, 2010, a Tupolev 154 aircraft crashed near Smolensk, Russia, killing all 96 people on board, including the Polish president. Satellite imagery of the accident site was acquired from the WorldView-2 satellite and archived. This imagery was then provided to Cranfield courtesy of DigitalGlobe for research purposes.

WorldView-2 is a high-resolution multispectral satellite and is one of the most recent commercial satellites available. It was launched in October 2009 and is capable of producing high-quality images with a resolution 0.46 m for panchromatic and 1.84 m for multispectral. In addition to the traditional red, green, and blue bands, it also offers two near-infrared bands, a red-edge band, a yellow band, and a coastal band. Using the latter band, WorldView-2 has the ability to perform bathymetry (measurement of depth in water).

The image in Figure 4a clearly shows the wreckage trail in the top right corner. It also shows the vehicles, tents, and access routes being used by emergency services and investigators. It is clear from this figure that at this resolution, a trained analyst could easily identify this wreckage trail as the location of an accident. However, this image represents an area of approximately 150 m by 100 m. Clearly, at this magnification, the time taken to manually search, say, 20 km by 20 km would be considerable, although not completely impractical.

Figure 4b shows the same image zoomed on the wreckage trail with the rear section of the aircraft in the center of the image. Other footage of the accident site suggests this piece is of the order of 10m in length, which is consistent with the number of pixels depicting it. However, unfortunately, this is clearly a high-energy accident resulting in significant destruction of the aircraft, and hence it is difficult to distinguish many other parts of the aircraft.

Although satellite imagery had no role to play in the analysis of this specific accident, it provides a valuable proof of concept, particularly because it uses one of the highest resolution commercial satellites available, WorldView-2.

Conclusion

The growth in commercial satellite imagery means that access to imagery is widely available. However, as the discussion has outlined, the tasking and acquisition of this imagery is not trivial, with a wide range of factors and parameters to be taken into account. It would be prudent for organizations that may wish to acquire commercial satellite imagery to contact an imagery provider in order to establish their typical requirements in advance of requesting imagery. This is particularly important if imagery is required quickly, say, in response to an accident at sea where buoyancy may be time limited.

Commercial satellite imagery is not yet of a quality to replace ground imagery or handheld imagery taken from a helicopter. However, the results of this trial and example have shown that there is potential utility in commercial satellite imagery for both wreckage location and wreckage plotting in specific situations. However, there are a wide range of factors affecting performance that are outside the control of the investigator, including wreckage and scene color, wreckage size, acquisition geometry, etc. The perceived risk of a wasted collection posed by these factors will obviously depend upon the situation faced by the investigator.

Future plans for research in this area include further trials into higher resolution multispectral satellites and the possible use of radar and hyperspectral sensors for detection of fuel and oil patches for location of accidents at sea. ◆

Acknowledgements

The authors would like to gratefully acknowledge the support provided by the UK Ministry of Defence, the UK Air Accidents Investigation Branch (AAIB), the Defence Science and Technology Laboratory (DSTL), and infoterra (UK and GmbH).

Safety Reporting And Investigation—Cornerstone of SMS

Although the 1979 DC-10 crash on the slopes of Mount Erebus occurred long before the concept of an integrated safety management system, there were elements of SMS already in place.

By Paul E. Mayes, Vice President, ISASI

(This article is adapted, with permission, from the author's paper entitled The Contribution of Safety Reporting and Investigation to safety management systems *presented at the* ISASI *2010 seminar held in Sapporo, Japan, Sept. 6–9, 2010, which carried the theme "Investigating ASIA in Mind—Accurate, Speedy, Independent, and Authentic." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org.—Editor)*

Nov. 28, 1979, was a very auspicious date for aviation safety. That's the day of the worst aviation accident in the Australasian region—257 people lost their lives when a DC-10 impacted the slopes of Mount Erebus in the Antarctic. It was also a major impetus to changes in the way we investigate and analyze accidents.

Many investigations are complicated by engineering or operational issues requiring technical expertise. This aspect has become even more of a problem for the investigation of accidents involving later-generation aircraft with advanced systems and technology.

However, although the DC-10 was in 1979 still considered a very modern aircraft, the investigation was not confronted with such problems. The investigation on site was difficult due to the accident location on the slopes of Mount Erebus. But the investigation was relatively straightforward because the digital flight data recorder (DFDR) and cockpit voice recorder (CVR) were recovered almost undamaged. Dennis Grossi from the National Transportation Safety Board (NTSB) in Washington, together with Milton Wylie from the New Zealand Air Accidents Investigation Office, arrived on site on December 1 (2 days after the accident) and after a few hours returned to New Zealand with the DFDR and CVR.

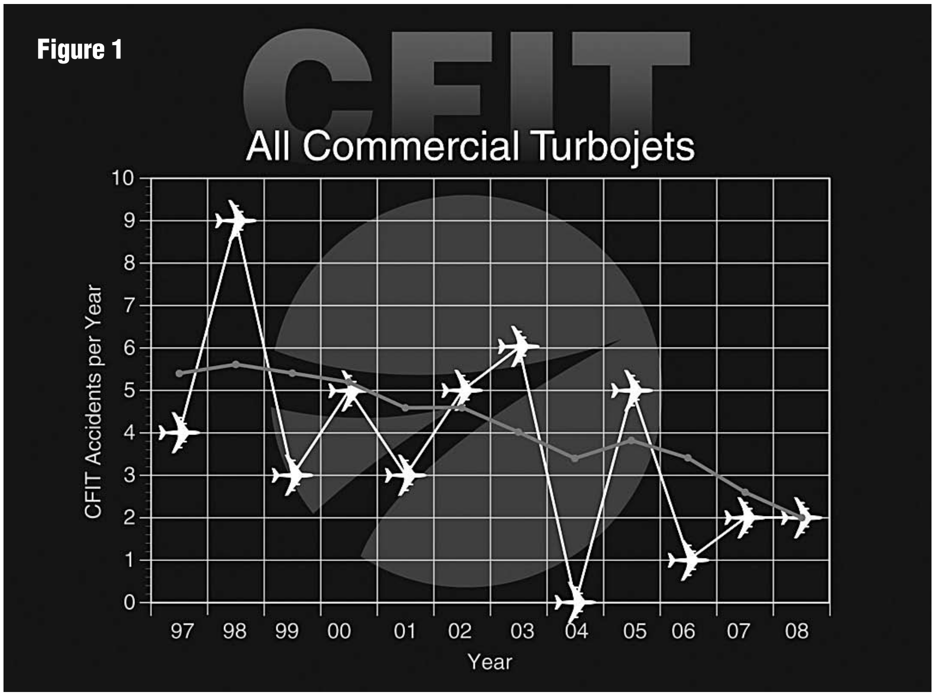
As New Zealand did not have the facilities to play back and analyze the recorders, they were taken to the NTSB laboratories in Washington, D.C. There the initial playback and analysis proceeded without difficulty. The obvious conclusion was that the aircraft had been fully serviceable and that this was a classic controlled flight into terrain (CFIT) accident. The term CFIT has been used now for many years as a "class" of accident. I personally find this term inadequate as it tends to dehumanize what are usually complex human performance accidents. CFIT accidents involving commercial turbojet aircraft still occur. Figure 1 shows a declining 5-year average, but only in 2004 were there no recorded CFIT accidents.

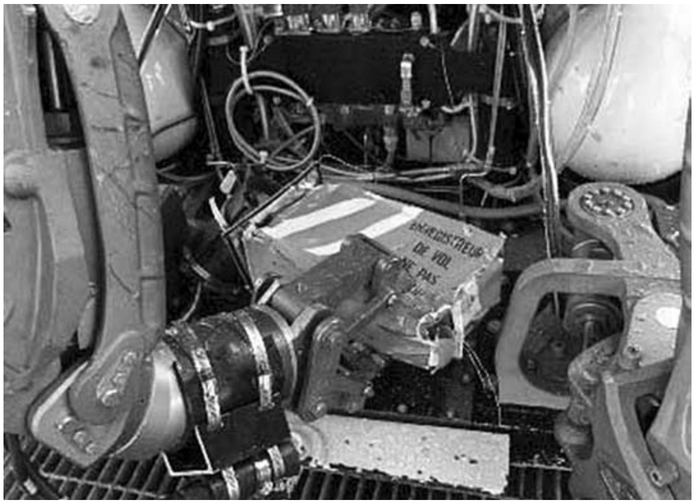
One of the advances since 1979 is the development of improved ground proximity warning systems, enhanced GPWS. The GPWS of 1979 that only gave an inadequate 6-second warning to impact in the Erebus case has been replaced by the EGPWS of today with its advanced terrain awareness features. All the CFIT accidents over the last 5 years have involved aircraft without an EGPWS fitted.

So the investigation of *what* happened was relatively straightforward based on the evidence from the DFDR. A serviceable aircraft had flown into rising terrain. The question or questions were why, why, why? These are often the most difficult questions to answer because they involve human beings and human performance. The cockpit voice recorder, or more aptly called the cockpit audio recorder, is often the key to answering these questions, even if the crew survives the accident.

In the case of the DC-10, the CVR was configured to record the cockpit audio signals in accordance with the FAA specifications. One channel records the audio picked up by the remote cockpit-area microphone centrally located on the flight deck. The other three channels record

Figure 1





Alaska Airlines Flight 261 CVR recovery.

the radio transmissions from each of the three pilot stations. In the case of Erebus and many other investigations up to that time, this arrangement of recording had proved to be less than optimum. As radio transmissions are not a factor in many accidents, the investigations would rely on the recordings from the one channel recording all the sounds from the cockpit-area microphone; the determination of what was being said was often difficult and open to misinterpretation.

In the Erebus case, although the background noise was low, there were five people on the flight deck, four flightcrew members and one flight commentator who relayed information to the passengers on the progress of the flight and the sights to be seen. Hence, the determination of what was said by which individual was not entirely without doubt.

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SMS elements

Although the Erebus crash occurred long before the concept of an integrated safety management system (SMS), there were elements of SMS already in place. One of these was an internal reporting system. The captain of the previous sightseeing flight to the Antarctic on November 14, 14 days before the accident flight, compared the coordinates of the navigation beacon at McMurdo and the waypoints that the flight crew had been given by the Navigation Department. He discovered that there was a significant distance between the two tracks, almost 30 nautical miles. He advised the Navigation section, which during the night prior to the accident flight "corrected" the waypoints. Unfortunately the captain of the accident flight was not advised of this change and was expecting the track to take them into the area of the McMurdo Sound rather than directly toward Mount Erebus.

As was demonstrated at Erebus in 1979 and at many subsequent accident investigations, the prompt recovery and analysis of the recorders are essential for the successful outcomes of complex investigations. But many accidents occur over water, and the recovery of the recorders from the seabed becomes a major exercise. The location of the recorders, and in many cases also the location of aircraft wreckage, depends upon the underwater locator device, which emits a sonar signal for 30 days when activated by water.

Since the mid-1970s, missing or damaged recorders have only prevented a full analysis of the accident in a small number of major accidents. Out of more than 3,000 accidents involving Western-built commercial aircraft, fewer than a dozen CVRs and FDRs have not been found according to the International Air Transport Association. And in most cases, enough wreckage was retrieved to piece together a probable scenario, although this could have taken many months and probably did not result in a definitive conclusion of why the accident happened.

Underwater searches were required for 26 aviation accidents over the last 30 years. The searches lasted anywhere from 3 days in the case of Alaska Airlines Flight 261, which crashed in the Pacific in January 2000, to more than 200 days to find the recorders in the Indonesian sea in April 2008 from the Adam Air Boeing 737 accident.

The Air France Flight 447 (Airbus A330) accident in the Atlantic was the most challenging as far as recovering the flight recorders—with three extensive searches before they were located and an estimated $40 million spent on the initial two searches

The research emphasis resulting from the Air France accident is on satellite technology to transmit critical safety information from the aircraft. The idea of sending real-time safety data to a ground station has been around for a while. Certain maintenance data are transmitted now, and was in the Air France case. However, technology does not currently allow large quantities of data to be transmitted due to bandwidth and cost. When considering that flight recorders have hundreds of parameters recording each second, to transmit that data to a ground station becomes very problematic.

One suggestion is to send basic flight information such as the heading, altitude, speed, and geographical location to a ground station on a regular basis. This is an interesting suggestion as it mirrors the original flight data recording requirements introduced in the 1960s, which were for a basic five or six parameters. These proved to be too limited for useful accident analysis. The easiest development would be to lengthen the duration of the locator signals. It has been suggested that the specification should be increased to 3 months. Other options for satellite tracking, such as EPIRBs, should be considered.

Despite ongoing studies of the potential for streaming data to a ground station during flight, the traditional onboard flight data recorder will still be the essential tool for air safety investigation. The reasons are the high costs of data streaming and the massive amounts of data currently recorded and often needed to understand the complexity of aircraft systems. A recent study found that even with a 50% reduction in current satellite transmission costs, the price tag for streaming data could be millions of dollars. Obviously, in today's financial environment this is not the most economic solution to the problem. However, the technology is available, and there are some military and commercial applications already in operation. So like many of the advances in aviation safety, this may well become an accepted practice in the future.

Let's return now to November 1979 and the implications for air safety investigation. The investigation was conducted in the established manner, collecting all available factual information, using the resources of the U.S. NTSB, the British AAIB, the equipment and aircraft manufacturers, the CAA, and the various organizations representing the company and the staff. This resulted in a standard ICAO Annex 13 report and included a probable cause of the accident.

For that time, there was nothing unusual in this approach. However, a royal commission was appointed to enquire into the Erebus accident. This commission had the advantage of not only the evidence from the investigation report but also the mandate to call witnesses from all areas associated with the aircraft, the aircraft operation, and the public. "By the time the hearings of the commission had concluded, every aspect of the disaster and its surrounding circumstances had been explored by counsel in considerable detail." However, the circumstances of the final stages of the approach without the advantage of the CVR and DFDR would never have been known.

The airline witnesses who appeared were intent on establishing pilot error as the effective cause of the accident. This was not unusual even in 1979 and late in the 1980s. A review of reports from that time, for example, will show that "pilot error" was still a common conclusion.

However, the Erebus Commission went much further. It looked into the company decisions, policies, and procedures as well as the actions of the board and the middle-manager levels. This was perhaps one of the first applications of the "Reason" model, which did not come into practice for another 10 years or more. But it certainly began the advances in air safety investigation where we looked back into the sequence of decision-making, training, and basic human factors and human performance. Later this became the standard for safety investigation through the work of James Reason and Patrick Hudson, among others.

Reason's work on causation and the development of his model is well known and has become a basic tool for investigations. It is interesting that in talking to flight crews from various backgrounds, most are familiar with the Reason model and the so-called Swiss cheese analogy.

If James Reason was the innovation of the 1980s and 1990s, safety management systems could be considered the next stage in the development of improved safety of operations. For many of us, safety management systems have been a way of life. It was not until ICAO defined safety management systems in 2005 that we realized what had become relatively commonplace for many of us. The regulations, eventually introduced by the Australian Civil Aviation Safety Authority as CAO 82.5 in 2009, defined the various elements and the need for a documented SMS.

Classic SMS

It seems we are bombarded with information about safety management systems these days in everything we read in the safety press and publications. The classic SMS includes elements of safety occurrence and hazard reporting and safety investigations. It could be argued that without a good reporting culture, the management of "safety" is almost impossible. If we do not know what is happening on the flightline or in the hangar, then we cannot make the necessary improvements to reduce risk and improve safety levels. Managers and supervisors will be in blissful ignorance of the real situation until a serious event occurs that cannot be ignored.

The ideal situation is that any safety hazard or safety concern is reported and action is taken to address these before they become an incident or accident. This is the utopia of preventive or proactive safety. In practice, this is very hard to achieve as operational staff members usually have very little time for non-operational tasks and do not perceive the benefit from reporting something "that did not happen."

Changing the mindset is essential if SMS is to be successful. It is also greatly assisted if the reporting process is simple and readily accessible such as being able to submit a safety report during the cruise phase, for example. Electronic reporting is ideal, but the use of paper forms is still widespread and effective. Forms can be completed after the end of a flight, at home, or in the hotel.

Safety assurance is accomplished through flight data monitoring, line operations safety audits, and safety actions from system improvement recommendations. An operator's SMS is an easy target for investigators after an accident. Determining why the SMS failed is not so easy. However, it has been reported that many smaller operators have met the letter of the legislation by constructing a SMS manual, in some cases supplied by external consultants. But the elements of SMS have not been rolled into day-to-day operations. Some of the reasons include cost and a reluctance to be open with the staff about safety issues. This must change if the promise of SMS in reducing accidents is to occur.

If we return to the Air France accident, it has been reported that pitot failures had been reported on the Airbus long-range fleet. Air France had reported problems to Airbus and Thales, the manufacturer of the pitot probes. The interim BEA investigation report documents the history of the probe issues, yet the risk of these failures did not appear to have been recognized. There may have been many reasons for this. These reports, for example, were only a small part of the total reports received regarding Airbus aircraft operations. The critical step in any SMS is to determine the severity and risk level associated with one or more reports and consequential potential for a catastrophic outcome. This is a fundamental step in a safety management system.

There is no shortage of occurrence reports and safety hazards identified by staff. Although we encourage open reporting of any safety concern, it is not always successful. From my experience, for example, an operator of 40 jet aircraft could expect 1,000 operational safety reports per year. Of these, less than 5% would be considered other than minor, low risk. The most difficult task is how to ensure that the reports that could be indicative of a critical failure, in the right circumstances, are treated with the appropriate level of response. Risk ratings are used as the main tool, but these are open to interpretation. Experience and corporate knowledge can be essential in this process. Some types of occurrences have obvious risks and are rated reasonably consistently.

However, other proactive (preemptive)

safety concerns can be much harder to risk rate. The concern of a line pilot may be an isolated instance and then it becomes a difficult judgment issue. Very often these safety concerns are related to changes in procedures, processes, or documentation. The investigation often finds that changed management procedures were not followed or were incomplete. Communications are the key, and they were lacking in November 1979.

In Australia, the Australian Transport Safety Bureau (ATSB) is the government safety investigation agency that has a mandatory reporting requirement. Any accidents or serious incidents, as defined by ICAO Annex 13, are immediately reportable including a death or serious injury, serious damage, or missing aircraft. However, the ATSB also has a list of further immediately reportable events that include such things as airprox, violation of controlled airspace, taking off or landing on closed or occupied runways, uncontained engine failures, fuel exhaustion, undershooting, over running or running off the side of a runway among several other event types.

The ATSB also has a class of reportable events called routine reportable, which have to be reported. These include injuries, other than serious, other than serious damage, a ground proximity warning system alert, runway incursion, and several other broad definitions related to aircraft performance, weather, loading, and air traffic system events. The result is that the ATSB receives around 15,000 notifications per year on average, 8,000 of which are accidents, serious incidents, or incidents.

However, the ATSB only carries out approximately 30 investigations per year. These potentially have greater systemic safety issues and are usually extremely complex, with fleet wide or worldwide implications. So less than 0.2% of reports are investigated. Another 0.2% are published as Level 5 factual reports where the operators' investigation reports are edited and published.

With so many reports, there will be issues that warrant investigation but that are not always obvious from one or two reports. A robust effective analysis system is essential to filter out the reports that can be indicative of a significant risk. The Civil Aviation Safety Authority is taking a greater role in the process of safety investigation to ensure that events of a regulatory nature are also covered. It is also concentrating on auditing the operator's safety management systems to ensure that the operator carries out a full and unbiased investigation so that safety lessons can be learned.

Analysis of serious accidents indicates that many established aircraft operators have exhausted the advances offered by the earlier safety management strategies developed in the late 1990/2000s and that new ideas are needed. A step for the better in airline safety performance took place around the year 2000, but those advances have become entrenched. And while safety today is at an all-time high, improvements in the safety rate stopped in the mid-2000s. The plateau marked a departure from a century of aviation safety that had shown a steady improvement since the Wright Brothers.

The review of accidents that occurred in the year 2009 shows that most were preventable. If accidents are analyzed by broad category, then runway excursions and incursions, and loss of control, are the main types of accidents in recent years. If we look at runway excursions, the majority can be linked to poor decision-making, breakdown in SOPs, and poor CRM. Most occur off an unstabilized approach, which results in landing long and fast. If we look back 10, 20, or 30 years, we see the same symptoms and the same results. Why didn't the crew execute a missed approach rather than persevering with a bad approach? The investigations have not had the optimal outcome of safety actions to prevent these reoccurrences.

Dr. Tony Kern believes there is a need for check and training organizations to reinforce basic flying skills so that pilots fly accurately and do not accept deviations from target speeds, localizer and glide slopes, and the required stabilized approach criteria—basic flying skills we were all taught during our training. There is a train of thought that we are not as diligent in our aircraft operations in an automated flight deck as we were in the previous technology flight decks.

What is beginning to evolve is the complexity of flying highly automated aircraft when the automation starts to fail. What is apparent from some situations is that the failure modes and degraded status of some automated flight decks can be very confusing. It would appear that the designs do not provide as much help or guidance to the flight crew as they should. With multiple failures or erroneous data inputs generating various confusing and sometimes opposing signals, the automated systems should ideally review and advise the flight crew on the most optimum response.

Although modern flight decks make a positive contribution to safety performance, pilots are not as practiced at manual flying as they used to be so that flying aircraft that have reverted to raw flight and navigational conditions becomes too demanding in difficult situations.

Since the year 2000, serious accidents have frequently involved pilot failure to manage situations that they should really have been able to handle successfully. The year 2009 was no exception. Examples include the Turkish Airline Boeing 737-800 at Amsterdam, the Colgan Air Bombardier Q400 at Buffalo, N.Y., the FedEx Boeing MD-11F landing accident at Narita, Tokyo. Notice that we are not using the term "pilot error" but rather looking at the human performance issues, the system designs, the training, and lack of understanding of the degraded states of the automation. Hence, the lessons from Erebus in 1979 are still very much part of safety investigation today.

In aviation, we are very proud of our safety record and the advances in safety over the years through technology and improving human performance. We are often compared with other modes of travel, and depending upon how you analyze the statistics, aviation comes out as the model for safety. However, as many analysts have commented, we may have reached a plateau and further improvements may be very hard to achieve.

In conclusion, in the 30 years since the worst accident in the Australasian region, there have been many important advances in technology, in systems, in understanding, and in influencing human behaviors and in safety assurance. However, it appears that we have reached a plateau in the quest for improved safety. We still have accidents that have the same elements of many previous ones and should therefore have been preventable. There is no shortage of reports, but the challenge for safety investigators is to have effective investigation findings and actions so that we can eliminate accidents such as runway excursions, loss of control, and CFIT once and for all. ◆

ACCIDENT TRENDS IN ASIA

MAJOR IMPROVEMENTS AND REMAINING CHALLENGES

The author uses accident data, exposure data, and other standard aviation measures to document where and to what degree positive change has or has not occurred in Asia and comments on remaining challenges.

By Robert Matthews, Ph.D., Senior Safety Analyst, Federal Aviation Administration, USA

(This article is excerpted, with permission, from the author's paper entitled Accident Trends in Asia: Major Improvements and Remaining Challenges *presented at the ISASI 2010 seminar held in Sapporo, Japan, Sept. 6–9, 2010, which carried the theme "Investigating ASIA in Mind—Accurate, Speedy, Independent, and Authentic." The full presentation, including cited references to support the points made, can be found on the ISASI website at www.isasi.org.—Editor)*

Several aviation systems in Asia have had low air carrier accident rates for decades, including Japan, Singapore, Hong Kong, and, depending on where the line is drawn, Malaysia. However, as recently as the early and mid-1990s, accident rates in the rest of Asia were fantastically high compared to the four countries noted above, or compared to rates in Western Europe and North America. That is no longer the case. A number of countries in Asia have achieved enormous gains in aviation safety and now have long-term accident rates that are among the lowest in the world, and several other Asian countries are approaching that level. The most impressive improvements include China, South Korea, and Vietnam.

On balance, aviation safety in Asia has become a good story to tell, but the good news is not shared by all countries. As we might expect with a geopolitical region as large as Asia, the pace of change has been uneven. In a number of countries, improvement has been less impressive, while recent trends have gone in the wrong direction in a few countries.

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Defining "Asia"

Terms like "Asia" or "Europe" often are defined slightly differently by different speakers. A non-Asian country makes the point well. Aviation officials in Mexico often joke that their country belongs to more regions than any other country. Some speakers include Mexico in North America, while others put it in Central America or the Caribbean or Latin America, or OECD—the Organization for Economic Cooperation and Development—countries (or not), or any of several other groupings. The same is true of certain countries that sometimes are included in "Asia" and sometimes not included.

Figure 1 illustrates the definition of "Asia" used in this article. It includes 29 countries with a variety of political and economic systems, a broad range of wealth, and national populations that range from very small at one end of the scale to three of the world's four largest countries at the other end of the scale. It is bordered from northeast to northwest by Japan, Mongolia, and Kazakhstan, on the west by Uzbekistan, Turkmenistan, and Afghanistan, the Maldives in the southwest, in the south by Indonesia, and in the east by the Philippines and several Japanese islands further east. Though this is a fairly standard definition, it excludes what some define as southwest Asia (or "the Middle East"). Finally, for the sake of clarity, it excludes the continent of Australia, as well as New Zealand and the Pacific states.

Changes in Asia's accident record

Table 1 compares 5-year hull-loss rates for the 29 countries of Asia to the rate of a "control group" of countries long recognized as setting a safety standard for the world, and then the rest of the world, including Central and South America, Africa, the Middle East, much of central Europe, plus Australasia. From 1990 through 1994, Asia had a hull-loss rate that was nearly 8 times greater than that of the control group and 38% higher than the rest of the world. Note that Asia's data for 1990–94 includes Japan, which then was, by far, the largest system in Asia, plus Hong Kong and Singapore, all three of which had already established safe systems. Without those three systems, the rest of Asia exceeded the hull-loss rate of the control group by more than 10 times and nearly doubled the hull-loss rate in the rest of the world. By 2005–2009, just 15 years later, the ratio for Asia was just a bit more than four times the rate for the control group and, instead of exceeding the rate for the rest of the world by nearly 40%, it was just less than half the rate for the rest of the world.

Though the improvement indicated above is dramatic, the aggregate data presented for all 29 countries obscures several

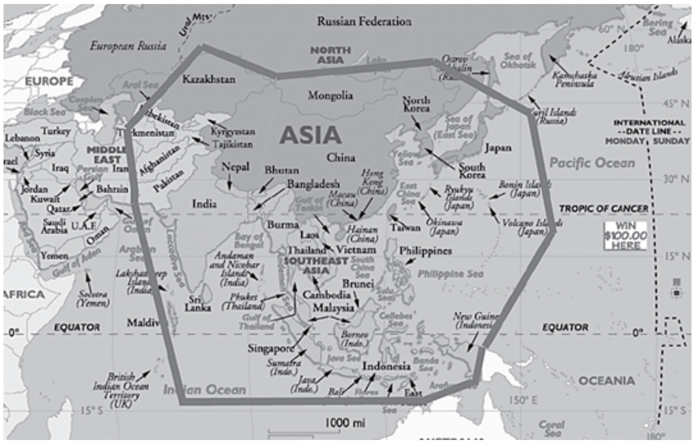


Figure 1. Definition of Asia for this paper: 29 systems—excludes southwest Asia ("Middle East").

Table 1. Hull Losses per Million Aircraft Departures 5-Year Rates, Asia Compared to Control Group and the Rest of the World

	1990–94	1995–99	2000–04	2005–09
Asia	4.61	2.91	1.42	1.52
Control Group	0.61	0.51	0.33	0.35
Rest of World	3.35	3.90	3.70	3.07

Control Group consists of Canada, USA, and the EU-15.

great success stories. Table 2 consolidates the data shown above into two 10-year periods for selected groups of countries. The table presents a telling story, supported by the data in Figure 2. Figure 3 presents a similar decade-to-decade comparison for selected, individual countries.

Table 2 shows that in the 1990s, the four countries identified earlier as having long established good safety records (Hong Kong, Japan, Malaysia, and Singapore) already had combined hull-loss rates that were only about half those of the control group. Over the next decade, those four countries compiled a hull-loss rate that was just 30% of the rate for the control group. In short, these four countries already had set the world's standard for aviation safety in the 1990s, only to extend the margin that the standard already had enjoyed compared to the rest of the world.

Japan, in fact, has not had a major fatal accident since 1985. With the world's sixth largest system measured by aircraft departures, Japan's only hull loss in 25 years occurred in 1993 when a DC-9-41, operated by the former Japan Air Systems, landed hard at Morioka-Hanamaki Airport. In that accident, all 76 occupants evacuated without injury, but a fuel leak led to a fire that eventually destroyed the aircraft. During the same two decades, Hong Kong had zero hull losses, and Singapore had one major accident at Taipei in October 2000, which was the lone fatal accident since 1972 from either Hong Kong or Singapore. Each of those systems is considerably smaller than Japan's, but they produced nearly 4 million flights over the 20 years.

The most dramatic changes

The story is perhaps most dramatic for the second group displayed in Figure 1 and Table 2 (China, South Korea, and Vietnam). Those three countries combined for a hull-loss rate in the first decade that was nearly seven times higher than the rate for the control group. Over the next decade, their combined rate was slightly lower than the rate for the control group. That is a very impressive change.

Table 2. 10-Year Rates for Selected Groups of Countries Per Million Aircraft Departures, 1990–99 and 2000-09

	1990–99	2000–09
Hong Kong, Japan, Malaysia, and Singapore	0.29	0.10
China, RO, and Vietnam	3.68	0.287
India, Taiwan, and Thailand	4.00	1.53
Indonesia, Pakistan, and Philippines	4.78	3.66
Central Asia (six countries)	10.59	5.20
Control Group	0.55	0.34

Vietnam had a very high hull-loss rate in the 1990s, followed by no hull losses the following decade. The high rate of the 1990s involved three hull losses produced by a very small system. Though the system remains relatively small, it has grown from fewer than 15,000 flights in 1990 to nearly 100,000 flights today. That rapid growth coincided with a sharp improvement in safety.

Much of that improvement came partly from upgrading the fleet, but some of it came as one benefit of opening up to foreign investment. Though Vietnam continues to struggle with the policy issues related to foreign investment and "foreign" brand names, the infusion of others' experience has contributed.

The improvement achieved by South Korea may be even more dramatic than Vietnam's. From June 1991 through December 1999, South Korean operators had eight hull losses in a system that then averaged fewer than 200,000 flights per year. Most of the eight accidents could qualify as egregious accidents, including three fatal accidents that killed a total of 304 people.

South Korea's Civil Aviation Safety Authority (CASA), along with its major carriers, KAL and Asiana, undertook an active effort to ensure appropriate training and establish and adhere to good standard operating procedures. The government and the industry also moved away from relying on punishment as a response to incidents or accidents, such as transferring authority in selected, lucrative markets from one airline to another after an incident. Instead, CASA upgraded its own staff and implemented more contemporary analytical procedures to improve safety throughout the system.

A closely related factor was pressure from the market. Both the U.S. FAA and the European Union, particularly the United Kingdom, restricted Korea's access to their markets until safety improved. Simply put, the loss of access to the world's biggest markets will get the attention of most companies. Simultaneously, international alliance and code-share partners pressed Korean carriers to upgrade safety and actively participated in the effort.

The results have been dramatic. After eight hull losses in just 9 years, South Korea has had no hull losses for the past 11 years, despite system growth of more than a third over that period. To everyone's credit, Korea's CASA and its carriers continue to invest resources and their administrative energies to ensure that the improvement is permanent.

Finally, China is perhaps the best recognized success story. Aviation and aviation safety have changed so dramatically in the past two decades or so that the change is hard to overstate. The early signs of change occurred in the 1970s when China first

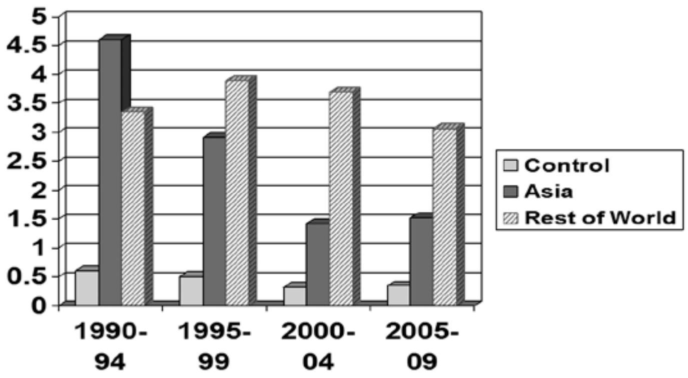


Figure 2. Hull Losses Per Million Aircraft Departures, All of Asia Versus Control Group*

*Control group consists of EU-15 plus USA and Canada. Rest of world includes South and Central America, Caribbean, central-eastern Europe, "Middle East," Africa, Australia, New Zealand, and Russia.

purchased a small number of Western-built aircraft, starting with Vickers and a small number of Tridents, followed by larger purchases of Boeing aircraft and more Tridents, and eventually Airbus aircraft. By the early 1990s, China had undertaken a conscious effort to retire most or all of its older, Soviet-era fleet and upgrade the fleet, again with Boeing and Airbus products and, later, Embraer and Canadair products. All these changes were accompanied or followed by significant investments in satellite-based air traffic control technology and a major effort to construct new airports throughout the country.

Different people may offer somewhat different time lines, but the profound change arguably began with a major structural change in the 1980s, when China's government reorganized the airline services operated by the Civil Aviation Administration of China into regionally based carriers. By the late 1990s, China restructured its industry again by consolidating the industry around three successful carriers. China Southern, which is China's largest airline, eventually absorbed China Northern, China Xinjiang Airlines, and Urumqui Airlines, as well as several subsidiaries of those former carriers, and it has a controlling interest in Xiamen Airlines. In the same period, China Eastern absorbed China Northwest Airlines, China Yuan Airlines, and Great Wall Airlines. China Airlines, which already had been structured as China's long-haul overseas carrier, remained based in that market and absorbed China Southwest Airlines.

Safety was a significant part of the rationale for the latter restructuring. In addition to restructuring its airline industry, China, much like South Korea did, also took strong action to ensure proper training and the establishment and adherence to good standard operating procedures. China simultaneously accelerated its fleet modernization, which introduced state-of-the-art automation, avionics, etc.

The net results have been dramatic. Throughout the 1980s and into the very early 1990s, China averaged two air carrier hull losses per year in an era when annual volume in China was the equivalent of about 1 week of exposure in the U.S. At that pace, we can only imagine the reaction if the U.S. were having a hull loss every week. However, in the 1990s safety improved substantially in China, though its hull-loss rate still was six times greater than the hull-loss rate among the control group. However, in the past decade of 2000 through 2009, China's hull-loss rate was slightly lower than the rate among the control group. The magnitude of that turnaround is simply stunning. See Table 2 and Figures 2 and 3.

The truly impressive part of this improvement in safety is that it has been achieved during very rapid growth in the system. Through the 1990s, China's airline fleet increased by an average of 13.3% per year, a pace at which the fleet would double every 5.5 years. In the following decade, the rate of increase averaged a comparable 11.9% per year, with the fleet doubling every 6 years. As one might expect, the number of revenue flights has increased at a comparable pace over the past two decades, averaging 12.1% per year.

China's aviation system has had a sustained and rapid growth. In 1990, the system had fewer than 300 aircraft and generated about 250,000 flights. These figures made China the 16th largest system in the world at that time. By 2005, China's system was the second largest in the world by either measure.

Rapid growth in any nation's aviation system can pose safety challenges. Yet China's aviation system has sustained a blistering rate of growth while simultaneously achieving nothing short of a revolution in safety. That combination is the truly impressive achievement. Yet, the rapid growth is part of the explanation for the improved safety. Not only did China retire its older, mostly Soviet-built fleet, but it continued to accelerate the introduction of ever-advancing state-of-the-art avionics and automation. That alone ensured a significant improvement in safety. Add the other efforts that China undertook, noted above, and the net result is a hull-loss rate that once was simply an embarrassment to one that, today, many countries must view with more than a little envy, and certainly a fair amount of respect.

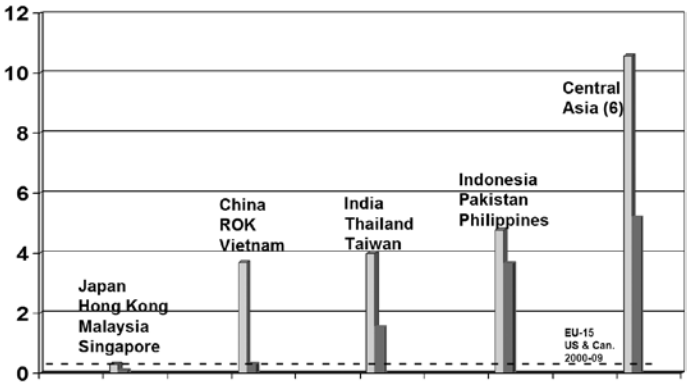
Countries with more modest improvement

India, Taiwan, and Thailand constitute a third group within Asia where hull-loss rates registered significant but more modest improvement than the successes noted above. Combined, India, Taiwan, and Thailand achieved a 62% reduction in their hull-loss rate in 2000–2009 compared to the 1990s. However, even with such a substantial decrease, since they started with very high rates, their combined rate for 2000–2009 remains well above either the control group or the seven Asian countries noted above. In addition, though Figure 3 shows all three countries achieved significant gains decade to decade, the hull-loss rates increased in two of the three countries in the past 5 years (2005–2009).

Taiwan achieved the most sustained improvement among these three countries, and for reasons similar to those that help to explain the positive changes in China and South Korea. Beginning around 1997, Taiwan's authorities accelerated its active oversight of the industry. Regional airlines, such as Formosa Airlines, were among the early targets, but China Airlines quickly followed. Aircraft and selected crewmembers were grounded or suspended for various periods, and the authorities initiated a sustained effort to improve crew training and the establishment of good standard operating procedures.

Taiwan also established its Aviation Safety Council (ASC). The ASC was responsible for regulation and accident investigation, but it also significantly upgraded the role of analysis and monitoring of trends.

However, Taiwan's improvement also was influenced by pressure from other aviation regulators. Much like South Korea, Taiwan's carriers found themselves either excluded from major



Source: United Nations

Figure 3. Change in hull loss rates, selected groups of systems, 1990–1999 (left) and 2000–2009 (right).

markets or found that future growth was precluded due to their high accident rates of the 1980s and mid-1990s. Those restrictions in major markets helped Taiwan focus its attention.

This did not prevent the takeoff accident at Singapore in October 2000, which killed 83 people. However, that is Taiwan's most recent fatal passenger accident. Taiwan's hull-loss rate has improved in each 5-year period. The rate for 2005–2009, at 0.8 hull losses per million revenue flights, was 83% lower than in 1990–1994. If Taiwan sustains its steady improvement, it soon will approach the very low rates enjoyed by the seven Asian countries noted above.

The hull-loss rate in India improved sharply through the early 2000s, leading to glowing commentaries similar to those about China's improvement. As with China, some of the improvement was explained by fleet modernization, with the government seeking to establish a 5-year cap on the age of passenger aircraft.

India's system has expanded rapidly since 2003. Prior to that, its system, measured by aircraft departures, doubled from 1990 to 2003. The pace of growth in that period, which averaged about 5.3% per year, was not dramatically higher than the increase experienced in much of the world in that era. However, since 2003, the system has expanded rapidly, averaging about 13.8% per year. Yet, despite this growth, India still generates just 4 million passengers per year in its domestic system, or about 2 days of passenger traffic in the U.S. Growth in supply has outstripped demand, creating excess capacity in many domestic markets, while leaving other markets underserved.

India's growth has created other challenges as well. New carriers have entered the market, some of which were short-lived, while others prospered and then encountered hard times, such as Kingfisher and Jet Airways, which now cooperate through a rather close alliance. In the meantime, India's former domestic trunk carrier, Indian Airlines, has been absorbed by Air India, with many of the normal difficulties of any large airline merger.

Though a cause-and-effect relationship may or may not exist, the improvement in India's accident rate has been reversed in recent years. A spike of non-fatal hull losses in just more than 4 years began in October 2005. That spike was followed shortly by the India Air Express accident in May 2010, in which 158 people died. Though that accident is not part of the rates computed for this work, it dramatically makes the point that the sharp improvement in rates has reached at least a temporary interruption.

The good news is that India has responded by developing comprehensive aviation legislation and by reorganizing its regulatory structure to ensure a more independent and stronger regulator. Nevertheless, judgment on long-term improvement needs to wait.

In Thailand, the system expanded rapidly in the early 1990s, stagnated briefly, and then expanded rapidly again from 2000 through early 2007. Since then the system has contracted by about 15%. Like other countries, Thailand has had several new carriers enter and exit the system, and had to cope with the Asian financial crisis of the late 1990s and then the SARS scare. However, political uncertainty probably is the greatest current source of erratic growth patterns in the industry.

No improvement or marginal improvement

Figure 3 shows that the accident rate actually deteriorated in recent years in significant parts of Asia or improved only marginally. The hull-loss rate in the Philippines improved slightly from 4.5 per million departures to a still very high 3.8 per million. Elsewhere, Indonesia's hull-loss rate increased slightly from an already high level of 5.4 per million departures to 5.8 in 2000–2009, while Pakistan's rate jumped from 2.7 to 8.15 per million departures. In the six countries of central Asia, the rate improved by exactly half, from a very high level of 10.6 hull losses per million flights to 5.3 per million.

Indonesia's rates increased in the second half of the 1990s, and then increased again over the past 5 years. In the Philippines, the rate also increased in the latter 1990s but increased again in 2000–2004, albeit marginally, then decreased in the past 5 years. But the rate remains very high compared to all the countries discussed above. Pakistan had no hull losses for 6 years (1995 through 2000), but its rate inflated again in 2000–2004 and remains very high.

Finally, the six countries of central Asia show an erratic pattern for rates over the two decades. Part of that is the problem of small numbers. A single accident or the avoidance of a single accident will significantly affect the computed rates for this region. Nevertheless, other factors help to explain the erratic pattern. For example, the rate for 2000–2004 is only a small fraction of the rate for the periods 90–94, 95–99, 05–09, with a sharp increase once again in the past 5 years. To a large degree that pattern reflects the virtual disappearance of aviation activity in Afghanistan from 2000 to 2004, followed by the reemergence of limited civil aviation activity in 2005–2009, accompanied by the reemergence of accidents.

Summary of trends

Several national systems in Asia have had good safety records for a long time, and their fatal accident rates continue to be among the lowest in the world. They include Japan, Hong Kong, Malaysia, and Singapore. China, the Republic of Korea, and Vietnam have achieved dramatic improvement and have joined this club, while Taiwan/Chinese Taipei is rapidly approaching this level. However, the pace of improvement has been slower elsewhere or in some cases it has been negative. In short, the pace of change has been somewhat uneven, but the overall story is good.

Remaining challenges

Asian countries that have long enjoyed safety civil aviation systems and those countries that have achieved impressive gains in the past decade or so generally will continue to enjoy the benefits of a civil aviation system that becomes increasingly safer. However, this will not come without some challenges. Many of those challenges will occur within the domain of the aviation community, but some will come from the broader economy. The aviation community will be able to act upon some challenges, but others are external to aviation. The mix and severity of challenges will vary, but most systems face one or more of the following:

- **Adequate domestic workforces.** Countries with rapidly expanding systems will have to meet an equally rapid increase in the demand for pilots, controllers, mechanics, and managers, which in turn will place demands on or be affected by educational systems, demographics, and access to the economy enjoyed by the entire population.
- **Competing demands for national resources** where human development needs are great.
- **National challenges of basic governance and stability.** These issues are or have been resolved in some countries, but are chronic or newly emerging in others.
- **Rapid expansion of low-cost carriers (LCC).** Though LCC inherently suggests nothing more than an alternative business model, it implies nothing more than a business model that need not have any inherent implications for safety. Nevertheless, the LCC expansion also implies some level of overall volatility, the possibility of rapid entry and rapid exit from the industry, and the possibility of rapid growth for some successful LCC operators. All this, in turn, imposes challenges of resource allocation on the regulator, the ability to reallocate those resources quickly in response to entry, exit, and expansion, and a general sense of scale for the regulator as the sheer number of operators expands.
- **Entry by several countries into the manufacturing of air transport aircraft** (China, Japan, and India), while some countries are significantly expanding their presence in the maintenance and overhaul industry (Singapore and Malaysia). All this is a great opportunity, but it also requires the development of a basically new regulatory capacity in design, production, and continued airworthiness.
- **Getting ready in some countries for growth in general aviation**, such as a small but rapidly growing civil helicopter market in India and a promising market for corporate aviation in China. Again, this is an opportunity, but it also requires the development of basically new regulatory capacities, plus a shift in operating environments.
- **Aviation infrastructure.** As or if systems continue rapid expansion, which everyone expects will be the case, some countries may have difficulty keeping pace with the demands on aviation infrastructure. The recent accident in China is a case in point as is the recent Air India Express accident at Mangalore. At Mangalore, the aircraft landed 5,000 feet down an 8,000-foot runway, overran at high speed, and traveled down a steep embankment at the end of the runway. The same accident in many richer countries likely would have occurred with a longer runway remaining after touchdown and with an overrun area or at least the absence of obstacles at the runway end. Though the result in a richer country may not have been benign after landing so long and so fast, it likely would not have produced 158 fatalities.

China, where some of the most dramatic improvement has taken place, may provide the best single example of how many of these challenges might interact. First, airline travel, though certain to continue expanding at impressive rates for another decade or so, eventually will flatten out as the industry faces increased competition from other modes of transport. Though airport investment has been nothing short of dramatic, it pales compared to China's recent and continuing investment in rapid rail and roads. Rapid intercity rail already is shifting travel from air to rail in some interurban markets, with corresponding reductions in airline capacity in those markets. Roads eventually also will become a major modal challenge within certain markets, depending on the time and distance between cities.

China, like several other countries, also is entering the field of civil aircraft manufacturing. New domestically produced turboprops and regional jets, and the spin-off technological benefits to the entire economy, are clearly an opportunity for China. However, entry into that market requires the development of a basically new regulatory capacity in design, production, and continued airworthiness. That challenge will not be unique to China, as other Asian countries also are preparing to enter that market.

Even the recent boom in airport construction has introduced risk, with serious doubts about some airport locations. Those doubts likely will be part of the ongoing investigation into the recent Henan Airlines accident at Yichun Lindu Airport in northeastern China, where an Embraer E190 flew into terrain in heavy night fog. Site selection for that airport had become controversial months before the accident, when China Southern abandoned night flights into the airport.

Conversely, with continued rapid growth ensured for at least the next decade if not more, China could be challenged to produce the broad range of professionals that any large, modern aviation system requires, from pilots and air traffic controllers to managers, mechanics, etc. China soon will have to meet this challenge just as its working-age population begins to decrease. Most demographic projections cite 2014 or 2015 as the watershed year when that decrease is likely to begin. Total population could decrease by as much as one-third in the following several decades, as India, with the opposite demographic future approaching in the next couple of decades, likely surpasses China as the most populous country by about 2030 or sooner.

China's aviation system also could face challenging demands for resources in other sectors of the economy. Despite the truly impressive gains in national wealth, China, in fact, remains a fairly poor country, with a GDP per capita that ranked 102nd. The challenge, of course, will be to expand the benefits of the recent growth further down into the population, especially the rural population.

Yet, if China succeeds in this challenge, and few concrete reasons exist to suggest China will not succeed at least somewhat, the aviation industry would benefit from an increase in the share of the overall population that could then afford to fly. In short, the aviation industry in many countries might envy China for having such "problems." In the end, despite real challenges, the next decade or two should continue to be an impressive period for aviation in China. The same may be true of Asia's aviation system in general over the next decade or two.

Conclusions

Asia has achieved dramatic improvement in aviation safety over the past decade to 15 years. However, like any other region, improvements in Asia have been uneven. Yet, despite different challenges that face different countries, Asia has a good story to tell, and the story should continue to get better for the foreseeable future. ◆

NO MORE CHEESE PLEASE

Accident Modeling From Symptom To System

The authors present a framework for safety enhancement based on a new view on human error, a dynamic systems engineering design approach, analytical forensic abilities, and institutional conditions for independent and qualified accident investigations.

By John Stoop, Delft University of Technology and Lund University, and Sidney Dekker, Key Centre for Ethics, Law, Justice, and Governance at Griffith University

(This article is adapted, with permission, from the authors' paper entitled Limitations of "Swiss Cheese" Models and the Need for a Systems Approach *presented at the ISASI 2010 seminar held in Sapporo, Japan, Sept. 6–9, 2010, which carried the theme "Investigating ASIA in Mind—Accurate, Speedy, Independent, and Authentic." The full presentation, including an index of cited references to support the points made, can be found on the ISASI website at www.isasi.org.—Editor)*

Although accident models have been applied on a large scale in practice, a reflection on their methodological assumptions, scope, and deficiencies reveals several schools of modeling. Several surveys indicate consecutive generations of models, their poor methodological basis, absence of a systems approach, and a focus on the application of models by lay people (Benner, 1975, 1985, 1996, 2009; Sklet, 2004; ESReDA, 2005). The first accident causation models, as derived by Heinrich, referred to accident analysis by metaphors, such as the Iceberg Principle and Domino Theory. In a second generation, Bird and Loftus applied a linear causality, while Kjellen introduced the deviation concept. Multi-causality was introduced by Reason, defining accident as an interaction between latent and active failures; and in order to avoid such interaction, a proactive involvement of top management is needed.

Based on attribution theory, Hale and Glendon were concerned about how people process information in determining the causality of events. They focused on the non-observable elements of the system: perceptions and decisions. While Reason developed his model on organizational accident causation, a next step was taken by Hollnagel, who identified the system as the full context in which errors and accidents occur.

A gradual development of accident modeling shows three generations of human error modeling, from a sequential accident model via human information processing accident models toward systemic accident models (Katsakiori et al, 2008). The evolution expands the scope of the investigation from sequencing events toward a representation of the whole system (Roelen et al, 2009). In practice, however, such accident modeling based on the Reason model proved difficult to apply, resulting in an increasing amount of varieties and simplifications (Sklet, 2004).

Most of the models restrict themselves to the work and technical systems levels and exclude the technological nature and development of the inherent hazards. Sklet concludes that this means that investigators, focusing on government and regulators in their accident investigation, to a great deal need to base their analysis on experience and practical judgment, more than on the results from formal analytical methods. Much of the accident data are conceptually flawed because of the inadequacies of underlying accident models in existing programs (Benner, 1985). Due to these pragmatic objections, during the conduct of an investigation, the limitations and mutual dependence between causation model and investigation methods should be explicitly taken into account. (Kletz, 1991; Sklet, 2004; Katsakiori et al, 2008).

Over a period of about 20 years, the Swiss cheese model of Reason has gained popularity among many accident investigators and has become a benchmark of investigation practices. In particular, the transformation of the concept of hazards, mitigation strategies, and managerial intervention capabilities into a communication metaphor has supported the dissemination, providing transparency into risk management for lay people and practitioners (see Figure 1).

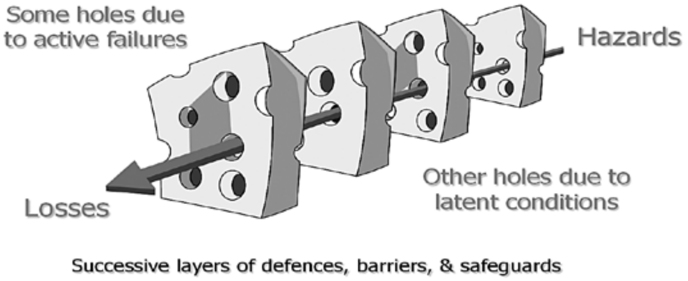


Figure 1. Reason's "Swiss cheese" model of organizational accidents.

The Reason model

The widespread application of the metaphor, however, also has raised concern from a scientific perspective and has raised questions on the application as an analytic tool during accident investigations (Dekker and Hollnagel, 2004; Leveson, 2004; Young, Braithwaite, Shorrock, and Faulkner, 2005; Dekker 2006). Also Reason and Wreathall, who created the metaphor, have some concerns about the practical application as an analytic tool.

Concerns of the Swiss cheese metaphor applied as an investigation model can be categorized as

- Remote factors have little causal specificity, are mostly intractable, and have no predictive potential. Their impact is shared by many systems and shift error up the ladder and do not discriminate between normal and deviant system states or take system dynamics into account.
- There are no stop rules in the expan-

sion of the scope. The more exhaustive the inquiry, the more likely it is to identify remote factors. As such, it is a representative of the epidemiological school of thinking, dealing with a linear agent-host-environment model.

- It assumes technology as a constant, and focuses on barriers, rather than hazards, reducing risk management to a control issue, not a systems adaptation and redesign issue. It lacks resilience and adaptation on the level of systems architecture and configuration.
- It does not deal with uncertainty and knowledge deficiencies, nor does it take into account the variety of operational conditions and systems states expressed in an encompassing operating envelope. As such, the model is linear and single-actor based in its control potential, not taking into account a systems perspective and a multi-actor environment.
- The model is normative and deals with implicit standards of performance by compliance with rules and regulations and a normative concept of failure instead of recovery and reliance on human performance capabilities.

Similar to a technical toolkit for repairing technical systems, an accident investigator has to be able to choose proper methods, analyzing different problem areas (Sklet, 2004). This raises the issue of ethics involved in selecting an investigative method. It is of particular significance that hypotheses can be validated and falsified during the investigation process. If not, it requires additional losses to validate hypotheses and to permit a pattern recognition or statistical analysis (Benner, 1975 and 1985). Finally, such modeling and accident phenomenon perceptions do not comply with the needs of investigators: a translation of human error models to practical investigation tools is still in its early phase of development (Benner, 1996; Strauch, 2002; Dekker, 2006). Investigation methods should support the visualization of the accident sequence, providing a structured collection, organization, and integration of collected evidence, and identifying information gaps in order to facilitate communication among investigators (Sklet, 2004).

Developing such methods in the domain of human behavior will require a shift of focus from inferred and uncertain states of mind toward characteristics of human factors (Dekker and Hollnagel, 2004). Rather than allocating the cause of an accident to human error by complacency, loss of situational awareness, or loss of control, the analysis could focus on falsifiable and traceable assertions, linked to features of the situation and measurable and demonstrable aspects of human performance (Dekker and Hollnagel, 2004). Rather than focusing on hypothetical intervening variables, more manifest aspects of behavior should be recorded during an investigation. While accuracy and comprehensiveness are rarely criteria for explanations, plausibility and credibility are. In addition, it becomes a necessity to shift the focus from the performance of an individual toward the performance of a joint system, according to the principles of systems engineering.

The analysis should look at the orderliness of performance rather than the mental states of operators. If such an orderliness of performance breaks down, this can be the start of further hypothesizing and investigations. This raises questions about the rationale of why the performance seemed reasonable to the operator at the time of the event (Dekker, 2006). Such a shift toward the systems level in identifying new knowledge during air crash investigations has been proposed by Benner, applying an event-based analysis, defined in terms of relations among events, set in a process and operating context. Such an approach permits a distinction between knowledge of systems processes and their operation and knowledge of the accident process. Such an event-based analysis should be favored because of the amount of new knowledge discovered, the relative efficiency of the search, and the timely availability of corrective action guidance. Such knowledge can provide more valid indications of comparative performances and events (Benner, 1985).

The Rasmussen model

Rasmussen takes this modeling issue one step further. He distinguishes the stable conditions of the past versus the present dynamic society, characterized by a very fast change of technology, the steadily increasing scale of industrial installations, the rapid development of information and communication technology, and the aggressive and competitive environment that influence the incentives of decision-makers on short-term financial and survival criteria. In answering the basic question: Do we actually have adequate models of accident causation in the present dynamic society, he states that modeling is done by generalizing across systems and their particular hazard sources. Risk management should be modeled by cross-disciplinary studies, considering risk management to be a control problem and serving to represent the control structure involving all levels of society for each particular hazard category. This, he argues, requires a system-oriented approach based on functional abstraction rather than structural decomposition. Therefore, task analysis focused on action sequences and occasional deviation in terms of human errors should be *replaced* by a model of behavior-shaping mechanisms in terms of work system constraints, boundaries of acceptable performance, and subjective criteria guiding adaptation to change. System models should be built not by a bottom-up aggregation of models derived from research in the individual disciplines, but top down,

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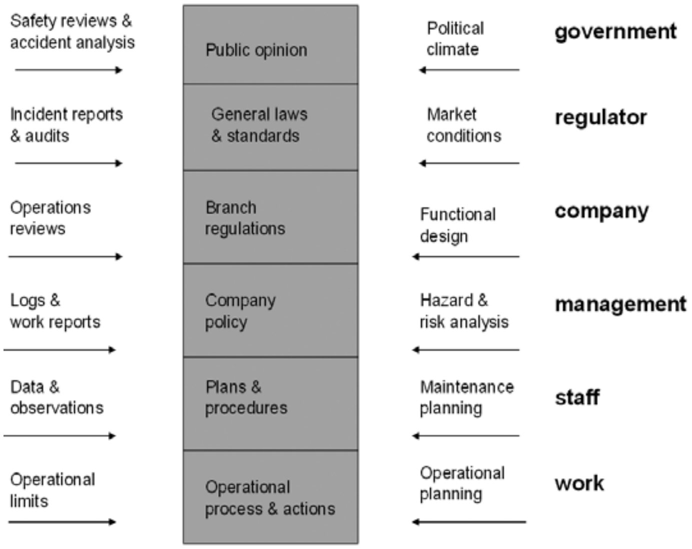

Figure 2. Rasmussen's systems hierarchy modeling.

by a systems-oriented approach based on control theoretic concepts.

His risk management concept is a control structure, embedded in an adaptive socio-technical system. Since decisions made in a complex and dynamic environment are not only rational and cannot be separated from the social context and value system, a convergence occurs of the economist concept of decision-making, the social concept management, and the psychological concept of cognitive control. Modeling task sequences and errors is considered not effective for understanding behavior. One has to dig deeper to understand the basic behavior-shaping mechanisms. Rather than striving to control behavior by fighting deviations, the focus should be on making the boundaries explicit and known and by giving opportunities to develop coping skills at boundaries. For a particular hazard source, the control structure must be identified, including controllers, their objectives, performance criteria control capability, and information available about the actual state of the system.

The fast pace of technology has led to the introduction of the "general due clause" and has enhanced the regulator ability to protect workers. Each employer "shall furnish to each of his employees a place of employment that is free from recognized hazards that may cause death or serious harm." By stating safety performance objectives, safety becomes just another criterion of multi-criteria decision-making and becomes an integrated part of normal operational decision-making. In this way, the safety organization is merged with the line organization and loses its independent position during the assessment. This requires an explicit formulation of value criteria and effective means of communication of values down through society and organizations. The impact of decisions on the objectives and values of all relevant stakeholders are to be adequately and formally considered by "ethical accounting" (see Figure 2).

Depending on the nature of the hazard sources, three different categories are defined, characterized by their frequency of accidents and the magnitude of loss connected to the individual accident:

- occupational safety, focusing on frequent but small accidents. The average level of safety is typically controlled empirically from epidemiological studies of past accidents.
- protection against medium-sized, infrequent accidents. Safety systems evolve from design improvements in response to analysis of the individual, latest major accident. Safety control is focused on particular, reasonably well-defined hazard sources and accident processes.
- protection against very rare and unacceptable accidents. In such cases, the design cannot be guided by empirical evidence from past accidents due to the very large mean-time between accidents.

Design and operation must be based on reliable predictive models of accident processes and probability of occurrences. A full-scale accident then involves simultaneous violations of all the designed defenses. The assumption is that the probability of failure of the defenses individually can and will be verified empirically during operations, even if the probability of a stochastic coincidence has to be extremely low. Monitoring the performance of the staff during work is *derived from the system design assumptions, not from empirical evidence from past evidence.*

It therefore should be useful to develop more focused analytical risk management strategies and a classification of hazard sources in order to select a proper management policy and information system. The dimensions of a taxonomy for classification depend on the nature of the hazard source and the anatomy of accidents. Rasmussen identifies only a limited series of hazards: loss of control of large accumulations of energy, from ignition of accumulations of inflammable material, loss of containment of hazardous material. When the anatomy is well bounded by the functional structure of a stable system, then the protection against major accidents can be based on *termination of the flow of events after release of the hazard*. When particular circumstances are at stake, the basis for protection should be on *elimination of the causes of release* of the hazard.

Defenses can be based on predictive analysis. The design of barriers is only accepted on the basis of a predictive risk analysis demonstrating an acceptable overall risk to society. When the predicted risk has been accepted, the process model, the preconditions, and assumptions of the prediction then become specifications of the parameters of risk management. Preconditions and assumptions must be explicitly stated in a probabilistic risk assessment (PRA). In this view, fortunately, it is not necessary for this purpose to predict performance of operators and management. When a plant is put in operation, data on human performance in operation, maintenance, and management can be collected during operations and used for a "live" risk analysis.

Thus, predictive risk analysis for operational management should be much simpler than the analysis for a priory acceptance of the design. Such performance data can be collected through other sources than accident investigations; incident analysis and expert opinion extraction may compensate for the lack of abundant accident data. According to Rasmussen, the models required to plan effective risk management strategies *cannot be developed by integrating the results of horizontally oriented research* into different features of hazard sources and systems configurations. Instead, *vertical studies of the control structure are required* for well-bounded categories of hazard sources, characterized by uniform control strategies (Rasmussen and Svedung, 2000).

Expansion toward "real" models

In accordance with the desire to create

more encompassing models in a dynamic environment, the Reason and Rasmussen model are superseded by a new series of risk management models. In shifting from accident investigation to other system performance indicators and their data on a daily basis, there is a need for modeling all possible causal event sequence scenarios in order to understand what is happening. Such an analysis should include technical, human, and organizational factors, deeming the Reason model to be insufficient, due to its theoretical and partial modeling and the amount of occurrences that have to be processed every day (Roelen et al, 2009).

There is a need for "real" models, covering every aspect and systems level, requiring a substantial mathematical background and user-friendly software tools. Such models should incorporate fault trees, event trees, and influence diagrams, which were adopted in the nuclear power industry in 1975. Sophisticated PRA methods should provide establishing a relation between cause and effect, while influence diagrams should represent the influence of the context. Since airline safety analysts, safety managers, and chief pilots have detailed knowledge but fail to identify systemic shortcomings, a framework is needed to help them to see the whole picture. Most of the effort is in classification of the data entry, with relatively little effort spent on analysis (Roelen et al, 2009). Such a "real" model should be integrated in order to represent the complexity and interdependencies, should be quantitative and transparent, and should provide reproducible results, covering the whole aviation system.

This approach does not favor the introduction of new concepts or models. The concepts of Dekker to see socio-technical complexity as a web of dynamic, evolving relationships and transactions or the Leveson concept of systems as interrelated components that are in a state of equilibrium by feedback and control are not considered useful (Roelen et al, 2009). The aviation industry should be too conservative and too slow responding in accepting new ideas, while Reason's Swiss cheese model is still relatively new. An event model that fits current practice should make more sense than to develop new models with a completely different concept, however correct these concepts might be (Roelen et al, 2009).

Modeling accidents

Across the various domains, accident investigation and event modeling have seen different points of departure. On one hand, there is a bottom-up approach in occupational risk and road safety: prevention of accidents and separating process safety from personal safety. Focus on isolated causational factors and single-actor strategies (corporate management or the three E's of engineering, education, and enforcement).

On the other hand, a top-down approach is applied in aviation, railways, and shipping aiming at systems change and learning without separation between personal safety, process safety, external safety, or rescue and emergency handling (ETSC, 2001). Modeling accidents by decomposing accidents into a limited category of hazards and a predefined set of generic failure types deprives the analysis of the following three major components.

—First, learning lessons for prevention of similar events. Prescriptive modeling of accidents forces the decomposition and description of the event into the format of the model. It also forces the event into an assessment of the correctness of the event in terms of compliance with the model's normative assumptions and notions. In particular, with human error modeling, such normative assessment remains implicit and obscures an explanation of the behavior, based on motives, conditions, constraints, and context.

Prescriptive modeling denies local rationality at the operator level. In particular, where pilots, mariners, and drivers have their discretionary competence, such modeling rather obscures than clarifies human behavior in high-tech operating tasks. Their adaptive potential to new situations and ability to respond and recover in a flexible manner is the basis of their learning. It is a part of their internalization process of processing experience into knowledge. In a normative assessment, the operator is assumed to have a timely and full transparent oversight over all the available information, systems properties, and of all his actions and their consequences. Such an investigator hindsight bias obscures the decision-making in uncertainty, which the operator is submitted to in practice (Kletz, 1991; Dekker, 2006). Such an analysis in which operator performance is assessed against normative behavior is in contradiction with learning theory. In particular, in complex high-tech systems, such an assumption of full and transparent information supply is not realistic and hence in conflict with bounded and local rationality theory.

—Second, cross-corporate dissemination of lessons learned. In the Durkheimian and Weberian tradition, social sciences copied the notions of the most prominent scientific domain of the 19th century, the natural sciences, to mirror themselves to their merits and to surpass them by adapting their methodology (Matthews, 1978). This mechanism in establishing scientific esteem seems to be repeated in the 20th century, by mirroring management control modeling against engineering design principles. In 1972, the psychologist Edwards claims a more prominent role for the behavioral sciences in the integral design of aircraft and postulates the HELS model (Edwards, 1972). A "traditional" focus on technical components should be unjustified, the "linear" design method an anachronism. This claim is even more interesting because it is stated at the very moment of the development and rollout of the major aviation innovation at the time: the first of the widebody generation of commercial jet aircraft, the Boeing 747.

In his plea for involving psychology into aircraft engineering design, Edwards also criticizes accident investigation in aviation: the value should be limited, the frequency too low to draw useful conclusions, while the complexity should prevent an adequate analysis. Edwards follows the criticisms of Frank Lees in 1960, who did not see an added value for accident investigation in the process industry. Frank Lees shifts a preference toward incidents, loss control, and risk management. According to Edwards, accident investigations should only be based on negative experiences, instead of positive experiences as well. Accident investigations should only be descriptive and lack explanatory potential.

However, international aviation is a global, open transport network that can function exclusively on the basis of mutual harmonization and standardization, high-level performance demands, and open access to the global network. Learning from an accident in aviation, therefore, takes place at the international and sectorial level, not on a national or corporate level, such as in the process industry or nuclear power supply. This learning is focused on technological improvements and open exchange of information at the level of international institutes such as the International Civil Aviation Organization (ICAO) instead of national governmental inspection and limiting learning to the level of the private, multinational company. Safety as a societal value is a prerequisite for the international transport community due to its existence as a public transport system.

—Third, its specific analytic potential. Modeling of accidents has been derived from the paradigm as defined by Lees and initially elaborated by Reason and Rasmussen for the process industry. It is a legitimate question, however, to see whether the inherent characteristics of the process industry are generically applicable in other high-technology and knowledge-intensive industrial sectors, such as the transportation sector.

There are fundamental differences between the process industry and the various transport modes. The most prominent differences in system architecture and characteristics between the sectors are

- closed versus open systems. In public transport, safety is a public governance value, managed in a dynamic network of mutually dependent actors and stakeholders. In the process industry, risk control is allocated to the corporate level from a top-down managerial perspective, dealing with fixed sites on a stand-alone basis. A company structure in the process industry is of a multinational nature, while entities in the transport modes are international by nature.
- continuous versus intermittent operations. The transport industries are operating on a 24/7 demand basis, providing direct and individual services at the level of global networks, while the process industry operates on a supply basis, facilitating intermittent production organization, creating room for temporary shutdown, reconfiguration, and adaptation of specific products without the requirements of a permanent availability of production capacity.
- the role of the human operator is fundamentally different. In transport modes, the concept of human-centered operations will be irreplaceable for decades, if full automation is ever desirable and feasible, such as in the process industry. Consequently, various cognitive levels of operations are required and various delegated responsibilities have to be allocated to the various control levels of the system.
- There are differences in the dynamics and pace of technological adaptation. In the transport modes, rapid adaptation by technological harmonization and standardization creates the basis for accessibility of the network, interoperability, and reliability for all actors. In the process industry, there is a more restricted pace of technological development, while the conversion of material properties produce only a limited set of hazards and critical events, such as fire, explosion, loss of containment, and health problems. In the transport modes, a wide variety of events in a rapidly evolving operating environment will occur, creating exposure to kinetic energy releases inherent to speed and mass. Consequently, managing the consequences of catastrophic failure is different.

It therefore is a legitimate question as to whether formal models on a managerial level of safety decision-making processes are appropriate for accident investigation and should replace metaphors or whether modeling, as such, is inappropriate for accident investigation of transport modes and should be replaced by another concept.

In overcoming present limitations and the necessity to achieve a shift from managerial control strategies toward a socio-technical systems perspective, the latter might be the case.

Toward new concepts

If we shift from managerial control strategies toward applying an engineering design approach to safety at the socio-technical level, what does this mean for the accident investigation process? How do we substantiate such an engineering design approach in the accident investigation methodology? How do we substantiate the concept of resilience engineering in practice (Hollnagel et al, 2008)? Two steps are to be taken into account: identification of the design solution space and the use of empirical evidence as an input for safety design specifications based on forensic engineering principles.

Safety-enhancing interventions can be categorized into two main classes:

- Linear interventions and first order solutions. Simple problems allow restricting the design space. This is valid only if the number of solutions is small, the number of design variables is small, their values have limited ranges, and optimizing within these values deals with sacrificing aspects among the limited set of variables. Such interventions reinforce the design space *in the detailed design phase* by reallocating factors, by more stringently complying with rules and regulations, and by eliminating deviations applicable to simple, stand-alone systems
- Complex interventions and second order solutions. Complex dynamic problems demand expansion of the design space. Such solutions focus on concepts and morphology, reallocating functions to components, reconfiguring and synthesizing sub-solutions, involving actors, aspects, teamwork, communication, testing, and simulation. Such an expansion of the design space occurs *in the functional design phase* by developing conceptual alternatives and prototypes applicable to complex and embedded systems.

When first order solutions fail and do not prevent an event, a redesign of the system becomes necessary.

In order to achieve such redesign, the event must be redefined in the first place by applying an engineering design methodology (Stoop, 1990; Dym and Little, 2004):

- *decompose the event* to identify contributing variables and their causal relations.
- recompose the event by *synthesizing safety critical variables* into credible scenarios.
- provide *analytical rigor* to the scenarios by identifying their explanatory variables, based on undisputed empirical and statistical evidence and scientific research.
- make the *transition from explanatory variables toward control and change variables.*
- develop *prototypes* of new solutions.
- test the prototypes by *exposure to the accident scenarios* in a virtual simulation environment.

Designing safer solutions

In designing safer solutions, two fundamental questions are raised about

- how to design safer solutions?
- how to generate the requirements for such a design?

In contrast with linear interventions and first order solutions, in complex systems there is no direct relation between a single contributing factor and its remedy. In redesigning safer solutions, there are three different focus groups for communication of the safety solutions: (1) operators and actors within the system able to achieve a safe performance, (2) knowledge providers for a better understanding of the system behavior, (3) and change agents, able to govern and control the system. Each of these parties has a specific set of communication means, applying, respectively, metaphors, models, or prototypes. Each of these parties applies its own vocabulary and reference frameworks, but should share a common notion in the end by a common means of communication. Applying a "barrier" notion is a powerful communication metaphor, but does not help in the case of a scientific modeling of the issue or applying a prototype in testing a solution.

Synthesizing solutions is necessary to establish a shared solution, based on the credibility, feasibility, compatibility, and selection of preferred alternatives in order to create consensus among all parties involved in accepting the solution. Synthesizing is about recreating interdependencies into a new concept, network, or configuration based on shared values. Complexity then can be defined as the interdependences of variables, choices, and design assumptions. To deal with this complexity, it is not sufficient to decompose a system or event into its contributing variables and explanatory variables within its existing solution space; the design variables must also be identified in order to serve as input for the systems engineering design process.

In addition, dealing with complexity and context does not mean adding more detail and levels to an event by increasing the decomposition. It does mean *providing transparency at higher systems levels* with respect to its functioning and primary processes, and clarification of the conceptual properties, and its configuration and composition. Increasingly complex accident modeling such as Accimap or STAMP does not make the transition from the event toward systems characteristics (Rasmussen and Svedung, 2000; Leveson, 2004). If the inherent properties of a system are not identified during design, they will manifest themselves as emergent properties during operations. Such properties are to be specified by stakeholders, actors, and other parties that are to be exposed to the system's operational consequences and formulated in an overall program of requirements, leading to design specifications.

To assess the integral performance of the system, a synthesis should take place of all aspects in an encompassing program of requirements. Such a program of requirements becomes a consensus document, in which all actors involved have had the opportunity to express and incorporate their requirements, constraints, and conditions during the assignment phase of the redesign.

A language issue, creating scenarios

In reconstructing an event sequence, we easily refer to the mechanical reconstruction from an engineering perspective. In unraveling the event sequence from a psychological or sociological perspective, we might prefer the phrasing of reenactment of the event or reconfiguration of the system state and operating environment.

Recomposition of an event enables event analysis. To communicate, a common reference framework as shown below is required, clarifying the various perspectives in recomposing the event:

- A technical perspective dealing with a *reconstruction* of the physical system performance.
- A behavioral perspective dealing with the *reenactment* of decisions and discernable actions.
- A systems perspective dealing with the *reconfiguration* of the systems state and operating environment.

To create a common understanding among actors, a common language and common notions are necessary. In risk discussions, the perception and acceptance of risk varies across actors, dependent on their position and interest. They may apply either a frequentistic or a scenario approach, dealing with either the frequency or the consequences of an event, a technological or a sociological approach, or may apply a rationalist or an empathic approach (Hendrickx, 1991). These different approaches each have developed their own notions and language. To facilitate communication, there is a need for either a common language or a translation between these languages. This implies an understanding of each of the languages in the first place with respect to its linguistics, syntaxes, grammar, and vocabulary. Decomposing such a language identifies the elements and building blocks of the language and facilitates analysis of their meaning and usefulness.

For communication purposes, however, a language cannot be spoken at such a decomposed level. A recomposition of these elements and building block takes place into a more complex communication structure to facilitate meaningful conversation. In an analogy with music, poetry, and literature, such a communication language is also applicable for accident analysis. The scenario concept provides such a common language, creating event narratives that form the basis for common understanding and agreement on the description of accident phenomena in their context. Achieving consensus on such accident scenarios provides a basis for a common risk assessment and shared solution space.

Shared solutions, redesign, and prototyping

In complex interventions, the focus is on events in a systems context rather than on isolated factors and generic aspects, such as is the case with linear interventions. The reconstruction of events takes place by identifying and synthesizing explanatory variables into scenarios in their specific operating environment and constraints. Such synthesizing is primarily evidence based. The redesign of the systems is conducted along the lines of engineering principles by generating design alternatives in the enlarged design space into the form of a limited set of prototypes. These prototypes contain a relocation and addition of functions, changing the morphology and configuration and incorporating additional actors and aspects. The testing of these prototypes is conducted by running scenario tests, defining limit state loads, and simulating complex, dynamic systems in virtual reality.

Analyzing system responses, before they are put into practice, are based on first time right and zero defect strategies. The responses of a system can be determined by a gradual enlargement of the disruptions, which are inflicted upon the system until oscillation and instability occur. Responses of systems may become visible by a gradual or sudden transition to another system state by passing a bifurcation point. After such a transition, the safety of the systems can be assessed according to the acceptability of the new safety integrity level.

Technology in itself contains many forms, incorporating invisible knowledge, notions, principles, and decisions from previous lifecycle phases. The physical

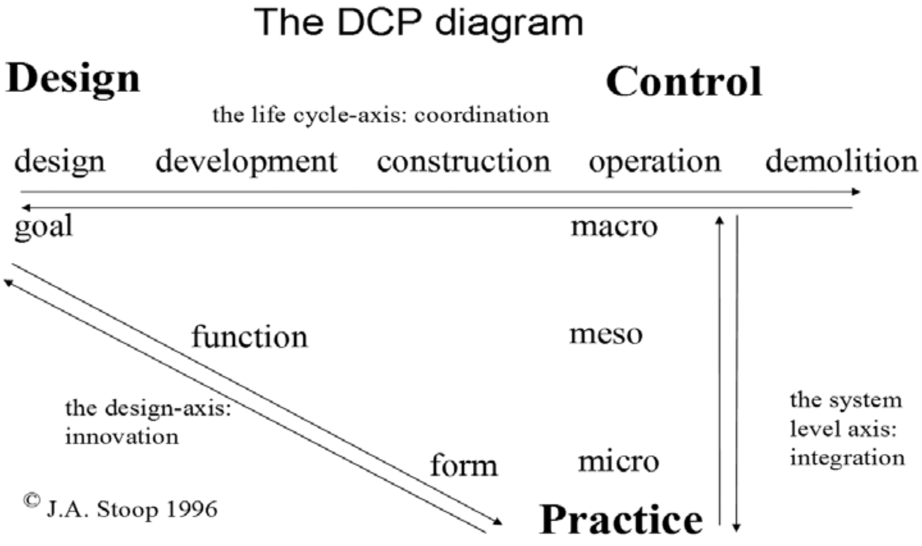

Figure 3. Stoop's systems architecture DCP diagram.

appearance of a product and process does not disclose inherent properties, principles, or interactions to end-users in their operational environment.

Design decisions are frequently made under conditions of high uncertainty. Safety margins and design standards, identification of failure mechanisms, probability assessment, consequence analysis, and identification of a design envelope should reduce the uncertainty again to an accepted level. Designers deal with optimizing performance and are not in a position to gain oversight into all uncertainties and unforeseen behavior of their designs (Petroski, 1991; Carper, 2001). Such behavior, however, can be designed into their processes such as with the Japanese design philosophy of limit state design or critical state design methodologies. Designers need an intellectual counterpart in assessing the safety of their design; accident investigators as forensic engineers play such a role.

Forensic engineering

Historically, designers needed a technical investigator capable of recomposing the actual and factual sequence of events, the operating conditions and context, and the factual technical functioning of the designs in practice. Such recomposition facilitated drafting redesign requirements. However, a recomposition ability should not only reproduce the physical reality, but also should encompass the knowledge, assumptions, decisions, and safety-critical issues that have been taken into account and assessed with respect to their acceptability. Such ability should also incorporate the ability to recompose the socio-technical context and operating environment.

From an investigator perspective, three kinds of systems designers should be supplied with a counterpart, each qualified with diagnostic and analytical skills from a technological/engineering design, organizational/managerial, or governance/control perspective in order to cover the architecture of the overall socio-technical system. This can be expressed in the DCP diagram (see Figure 3).

These three design-counterpart roles for investigators have been developing gradually over the past decades. Initially, with the development of technology, the technical investigator has matured, creating specialist approaches in many technological domains such as propulsion, structures, avionics, stability, and control.

Although the domain of human factors has seen major progress over the last two decades, the notions that have been developed in this domain are not yet readily applicable for investigation purposes (Strauch, 2002; Dekker, 2006). Translating theories on human factors into investigation tools is progressing, developing notions on bounded and local rationality, naturalistic decision-making theories, a blame-free view on human error, high reliability organizations, and resilience in organizational design.

In the domain of governance and control, the development is in an even earlier phase: this domain is developing classification schemes on failure, but is not yet in a phase of developing general concepts and notions of systems governance and control. Consequently, a framework and toolbox of investigation methods for conducting accident investigations at a systems level is not yet fully developed. Designers need counterparts for the assessment of their designs. Such a role is provided by accident investigators.

Conclusion

Although the Reason and Rasmussen models may well serve risk management in the process industry and nuclear power supply, there are doubts about their generalization toward the aviation industry. In practice, they are exposed to the risk of serving as reference metaphors for the benefit of risk communication and standards for generating generic, linear solutions. On methodological grounds, Reason's model shifts the focus from accident causation toward human error analysis, while Rasmussen's model replaces accident investigation by management control in a socio-technical systems context. Hence, both models do not comply with the needs of accident investigation theory and practices and systems engineering design needs in the aviation industry. Consequently, engineering design methodology may provide an alternative for improving the safety performance of complex systems at a socio-technical level.

The potential for systems engineering design in providing safer solutions requires

- identifying inherent properties before they manifest themselves as emergent properties.
- dealing with complexity and dynamics by focusing on functions rather than on factors.
- focusing on design principles and properties rather than optimizing performance.
- introducing systems dynamics by synthesizing interrelations into accident scenarios.
- applying a proof of concept by testing solutions in a dynamic simulation environment.

Therefore, it is necessary to

- develop event scenarios separated from systems models.
- develop prototypes of safer solutions.
- create dedicated virtual systems models, representing their specific characteristics.
- facilitate testing and validation in these models, parallel to the real system. ◆

ISASI Updates Membership Criteria; Expands Qualifications

The International Society of Air Safety Investigators (ISASI) International Council has unanimously voted to update its long-standing professional membership class criteria by expanding the qualifications needed to gain full member status into the premier professional organization of air safety investigators. Its present membership of 1,430 includes representatives from 67 nations.

This action results from recognizing that the role of accident investigator is transitioning from primarily that of "tin kicker" to one encompassing accident prevention beyond investigation. This transition is being brought on by the sharp reduction in the world's aircraft accident rate due to corrective actions resulting from past accident investigations, development of accident prevention processes in areas such as human factors, the explosion of information technology data-driven systems, and innovations such as safety management systems and other similar air safety enhancements.

The past requirement for ISASI full membership status was participation in a minimum of "eight intervening accidents" identified by date, location, make, and model of aircraft. Equivalent experience included "supervisory air safety responsibilities, safety committee assignments, participation in complex incident/mishap investigations, and/or hearings/boards of inquiry, etc." Five years of experience was also required.

The updated criteria for full ISASI membership includes—

An air safety investigator is one who has been actively engaged in the investigation of aircraft accidents, incidents, or conducted prevention activities to identify, analyze, eliminate, or control aviation hazards before they result in aircraft accidents or incidents. They may be representatives from aircraft manufacturers, air carriers, government agencies, the military, or members of other aviation professional groups. To be eligible for full membership, one must have three (3) years' experience in an aviation safety position involving aircraft accident investigation or prevention. An affidavit signed by a military applicant's supervisor will be considered when investigations or experience is classified. Aircraft accident litigation is not qualifying experience for this membership classification.

Commenting on the updated criteria, Ron Schleede, a former NTSB investigator and manager, past ISASI vice president, and current president of the Mid-Atlantic Chapter, said: "One of the reasons I encouraged the changes we made at the Council meeting stemmed from my experiences with more than two dozen airlines during Reachout Workshops and other teaching I have done for SCSI and Cranfield University. There were scores of airline 'safety' people who did not understand the limitations of the old application. Since many airlines may go 30 years without a fatal accident, there is insufficient 'business' for someone to qualify as a full member of ISASI under the old requirement. However, I know full well that most airline safety folks are conducting many, many 'investigations' on a daily basis. Some of them never go into the field—rather, they sit at a computer analyzing data and taking safety actions to prevent accidents based on the data. Others interview flight crews, etc., as part of their investigation duties. Still others are involved in related accident prevention work in cabin safety, dangerous goods, flight operations, airport operations, etc. I know that part of their daily work is investigation and prevention."

All persons who believe they are qualified under the new criteria are encouraged to visit ISASI's website at www.isasi.org for more information and to download an application form.

Once on the site, click on "About ISASI—join—individual." Please note that the website is undergoing an update and that the new membership application may not yet be posted, but will be in the very near future. ◆

ISASI 2011 Releases Event Technical Program

"The ISASI 2011 technical program is now available on the ISASI website for viewing," announced Jim Stewart, ISASI 2011 Technical chairman. He noted that the selection process of the technical papers to be presented was a daunting task because of the number and caliber of the submissions. To keep to the time schedule and to allow speakers sufficient time to explore their subject, only these 23 papers, originating from 10 countries, were selected for presentation:

- British Airways B-777 Investigation
- Flight Path Analysis
- Using "ASTERIX" in Accident Investigation
- Who Is Onboard in GA and Air Taxi Accidents?
- Preventing the Loss of Control Accident
- Building Partnerships in Unmanned Aviation Systems
- Teamwork in the Cause of Aviation Safety
- Long Distance Investigations
- Smaller Nations and Annex 13
- Timeliness, an Investigator's Challenge
- Major Investigations, New Thinking Ahead
- Post-Turbulence Structural Integrity Evaluation
- Analysis of Fuel Tank Fire and Explosion
- Elimination of Aircraft Accidents Through Flightdeck Technology
- Helicopter Design for Maintainability
- B-787 Safety Presentation
- Human Errors and Criminal Guilt
- Pilots' Cognitive Processes for Making

Inflight Decisions Under Stress

- Human Factors Standardized Procedures
- "Back to Basics" Still Works?
- Update on the AF 447 Investigation
- An Investigation Media/Communications Strategy
- Accident Communication in Today's Media

Key speaker for the event is Marcus Costa of the Chief Accident Investigation Section, ICAO. ISASI President Frank Del Gandio will open the air accident investigation conference following the general welcome by Capt. Richard Stone, Seminar chairman. Preceding the 3-day technical program is a full day of two tutorial workshops: Digital Photography for Accident Site Investigation and Improving Aircraft Integrity from Accident/Incident Analysis Information—Closing the Loop.

Registration is still open for ISASI 2011, the Society's 42nd annual international conference on air accident investigation to be held in Salt Lake City, Utah, USA, from Monday, September 12, through Thursday, September 15. The conference theme is "Investigation—A Shared Process."

The seminar's website is accessible through the ISASI website, www.isasi.org, and is now accepting registrations for both the conference and hotel accommodations. The seminar program registration fee (in U.S. dollars) before Aug. 15, 2011, is member, $550; non-member, $600; and student member, $200. A 1-day pass is $200; tutorial only, $150; and companion, $325. If registration is made after August 15, the fees are members, $600; non-members, $650; and student member, $225. A 1-day pass is $225; tutorial only, $175; companion, $350. The cost of a single event is—Welcome reception, $50; Tuesday night dinner, $100; and awards banquet, $100.

Full conference details may be found on the ISASI website or in the January-March 2011 issue of *Forum*, page 26. Registration information is also available via e-mail: avsafe@shaw.ca or via telephone: 604-874-4806. ◆

Reachout Completes Three Workshops

The ISASI Reachout program continues to deliver in diverse areas of the world with the completion of three programs in Almaty, Kazakhstan, in February; Doha, Qatar, in April; and Cairns, Australia, in May.

Reachout 39, held in Almaty, delivered topics that revolved around the key elements of incident investigation and safety risk management. The valuable training delivered by Caj Frostell and Mike Doiron was gratefully acknowledged by the 18 participants. The generous hospitality of Air Astana was instrumental in the success of the seminar.

Hosted by Qatar Airways, Reachout 40 was held in Doha and was instructed by Ron Schleede, who teamed up with Caj Frostell and Mike Doiron. They reinforced safety and investigation through instruction to 21 participants on safety risk management requirements for SMS and airline safety programs; incident investigation and analysis using the SHELL model; developing stress strategies and managing fatigue; government investigations; witness interviews; cabin safety investigation; developing the right safety culture; and mandatory incident reporting systems, among other subjects.

Reachout 41 was successfully hosted by ASASI in response to a growing need for safety-related training in Cairns, the remote area of north Queensland. ASASI volunteer instructors for the 4-day workshop, which 31 persons attended, included Lindsay Naylor, Paul Mayes, Rick Sellers, and John Guselli. They discussed emergency management, human factors, safety management, safety culture, and change and risk management.

Guselli, chairman of the Reachout program, said that the workshop received valuable support from ISASI corporate members, including the Australian Transport Safety Bureau and the Civil Aviation Safety Authority, with Aviation Australia providing excellent facilities and support at Cairns Airport. He noted that student feedback again illustrated the continuing need for this type of training in some of the more remote areas of Australia. ◆

ANZSASI Regional Seminar Scores Another Success

The New Zealand Society hosted the joint annual seminar of the Australian and New Zealand Societies of Air Safety Investigators in Wellington, New Zealand, on June 10–12. More than 75 people registered for the event, with another 12 partners present for the social functions. The reduced attendance seemed to reflect the difficult global economic conditions and perhaps the disruption caused by earthquakes in Christchurch, the initial choice of venue this year.

The program was well received by those attending, including the director of civil aviation for New Zealand, who was present for part of the first day. Although there were fewer presentations than usual on recent accident investigations, a wide range of technical and "soft" skills were covered. These included a presentation on the preparations being made by the Singapore Air Accident Investigation Branch for sea search and recovery, which was delivered by David Lim. Other presentations included a scientific experiment by Samuel Watson, the youngest-ever presenter at ANZSASI, on the release of carbon fibers in lightning strikes, analysis techniques and logic processes,

Some of the 75 people who attended the seminar.

performance-based navigation, aging aircraft, and national preparedness for handling the social expectations after a mass casualty disaster. The Reason model was revisited, practical skills in maintenance human factors were offered, and the work of the Asia-Pacific Cabin Safety Working Group was described. Presentations by a military investigator and a private investigator, who described their training and experiences, attracted much interest.

The Third Ron Chippindale Memorial Presentation was delivered by aviation lawyer Kim Murray, a former colleague of Ron's who spoke on the international and national law relating to the protection of ATC recordings and similar issues.

The opportunity was also taken to hold general meetings of the two national societies.

The next ANZSASI seminar will be held in Australia on June 1–3, 2012, at a venue to be announced. ◆

ISASI Member Rakow Shares B-737 Failure Analysis

ISASI member Joseph F. Rakow, Ph.D., P.E., and senior managing engineer with Exponent Failure Analysis Associates, recently shared with *ISASI Forum* and his clients an abstract of an investigation of fatigue cracks in lap joints of a fleet of 10 B-737 aircraft completed by Exponent 3 years ago. The abstract is printed as received.

"In March 2003, two through-wall cracks were discovered in fuselage lap joints of Boeing 737-200 aircraft operated by a major commercial airline. The airline suspected the cracks were associated with scribe marks created by an unapproved metal sealant removal tool employed by their painting contractor during a repainting process in the mid-1990s. The aircraft was retired, along with nine other aircraft that had been purchased and repainted in the same time period and had exhibited scribe marks in their lap joints. Exponent's investigation had two goals: 1) Identify the type(s) of sealant removal tool (metal, plastic, wood, etc.) that likely created the scribe marks found on the subject aircraft and 2) Estimate the number of cycles required for a scribe to grow into a through-thickness crack and compare that estimate to the service history of the subject aircraft.

"Through a series of experiments, Exponent's investigation demonstrated that unapproved metal tools produced scribe marks with physical characteristics (depth and shape) consistent with the scribe marks found on the subject aircraft, while approved plastic and wood tools produced much shallower and broader marks than those produced by the metal tools and, in some instances, with nearly undetectable depths. Only metal tools produced scribe marks with depths sufficient to initiate a fatigue crack (greater than 0.0026 inch, as determined by fracture mechanics), and only metal tools produced gouges with depths as large as those measured on the subject aircraft (0.005 inch, nearly twice as deep as the threshold). Fatigue analysis indicates that a scribe mark of the depth measured on the subject aircraft requires approximately 23,000 flight cycles to propagate a crack from the time of scribing to a through-thickness crack. The subject aircraft had accumulated approximately 22,000 flight cycles since the repainting process in the mid-1990s.

"This investigation highlights the sensitivity of aircraft structures to mechanical damage and emphasizes the extreme care that is required when performing maintenance and other services such as repainting."

The full investigation is currently summarized in a white paper available upon request. ◆

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Jakarta Pusat, Indonesia

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- Crystal Ferguson, Palm Coast, FL, USA
- Erica Garcia, Daytona Beach, FL, USA
- Thomas Haueter, Great Falls, VA, USA
- Deborah A.P. Hersman, Washington, D.C., USA
- Marc Hookerman, Lake Saint Louis, MO, USA
- Jeffrey Hutchinson, Lincoln University, PA, USA
- Robert Kelly, Ormond Beach, FL, USA
- Bobby Looney, Williamson, GA, USA
- Heather McCarley, Ladner, BC, Canada
- Heidi Moats, Leesburg, VA, USA
- Shane Murdock, Geelong, VIC, Australia
- Daniel Scalese, Los Angeles, CA, USA
- Daniel Siegenthaler, CH-6060 Sarnen, Switzerland
- Harriet Taukave, Nadi Airport, Fiji
- James Terrell, St. Peters, MO, USA
- Peter Upton, Auckland, New Zealand

NTSB Releases Year 2010 U.S. Aviation Statistics

The safety of civil aviation in the United States continued to incrementally improve across most industry segments in 2010, based on the preliminary aviation accident statistics recently released by the National Transportation Safety Board.

Twenty-six accidents were recorded for U.S. scheduled Part 121 airlines and six accidents on scheduled Part 135 commuters, all non-fatal.

Total accidents of on-demand operators (charter, air taxi, air tour, and air medical operations) decreased from 47 in 2009 to 31 in 2010, despite a slight rise in the number of annual flight hours from 2,901,000 to 2,960,000. However, fatal accidents increased from two in 2009 to six in 2010. The number of fatalities for both years was 17.

The decline in general aviation accidents in 2010 continues its downward trend, but this sector still accounts for the greatest number of civil aviation accidents and fatal accidents. There were a total of 1,435 such accidents in 2010, 267 of them fatal, resulting in 450 fatalities. ◆

Phoenix Conducts Flight 447 Critical Item Recoveries

Phoenix International Holdings, Inc. (Phoenix), an ISASI corporate member, is under contract to provide its 6,000 meter depth capable remotely operated vehicle (ROV) Remora for the recovery of critical items from Air France Flight 447. The downed Airbus has been the object of three extensive, but previously unsuccessful, search missions since its loss June 1, 2009, on a flight from Rio de Janeiro to Paris. Wreckage from the aircraft was successfully located on April 3, 2011, during a fourth search and was found lying in 3,900 meters of seawater.

The Phoenix-designed Remora is one of very few ROVs with the depth capability to search for and recover the flight data and cockpit voice recorders, two items that are of primary interest to crash investigators. Upon a successful conclusion of this essential task, Phoenix will be advised on the need to recover other objects from the aircraft. The experienced Phoenix ROV crew will then rig and recover every item of interest to the investigator-in-charge, Alain Bouillard of the French Bureau d'Enquetes et d'Analyses (BEA), and investigative team members. The recovery operation is being conducted from Alcatel-Lucent's CS Ile de Sein, a 140-meter-long telecommunications cable ship.

Phoenix has a substantial history of performing deep water search and recoveries for the airline industry. Past recovery projects have included Yemenia Flight IY626 (also conducted for BEA), Adam Air Flight 574, and Tuninter Airline Flight 1153. The company also provides search and recovery expertise to other publicly owned and private entities, the U.S. Navy, national and international agencies, and foreign governments. Phoenix is in its 11th year as prime contractor to the U.S. Navy for undersea search and recovery operations.

Phoenix provides manned and unmanned underwater operations, design engineering, and project management services to clients in the offshore oil and gas, defense, and other ocean-interest industries worldwide. Expertise is available from six regional offices in the areas of wet and dry hyperbaric welding, conventional and atmospheric diving, robotic systems, and tooling. The company's capabilities support plug and abandonment; underwater inspection, maintenance, and repair; construction; deep ocean search and recovery; and submarine rescue. ◆

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NTSB Vice Chair Hart Addresses

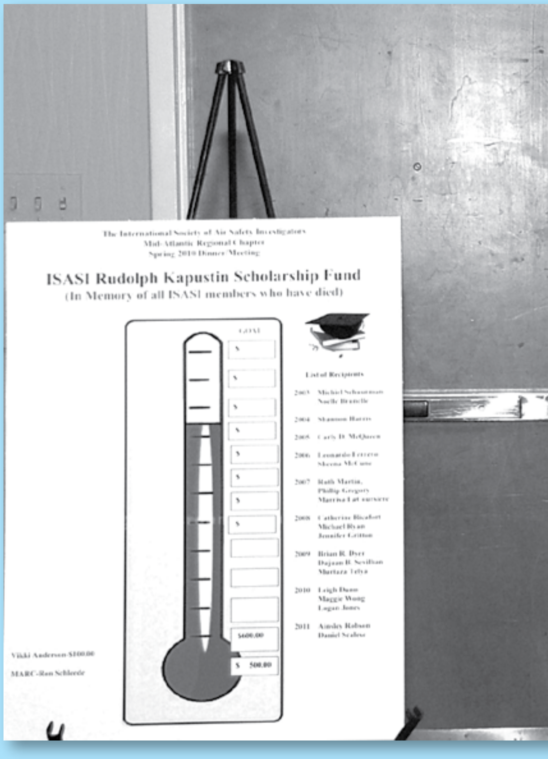
Vice Chairman Hart speaks to the loss of military-trained pilots.

NTSB Vice Chairman Christopher A. Hart was the guest speaker at the annual spring ISASI Mid-Atlantic Regional Chapter on May 5 in Herndon, Va., USA. He was sworn into office on Aug. 12, 2009, to serve the remainder of a 5-year term that expires on Dec. 31, 2012. Hart served a previous term as a member of the NTSB, and from 1994–2009 he was with the FAA. He holds a law degree from Harvard University and a master's and a bachelor's degree in aerospace engineering from Princeton University. He is a licensed pilot with commercial, multiengine, and instrument ratings.

In his opening remarks, Hart made clear that he was not speaking for the NTSB, but for himself, about three issues that he wishes to pursue while at the Board and which he believes need some serious attention: The loss of the military pipeline for air carrier pilots, criminalization of inadvertent error, and prioritization.

Regarding the military pipeline, he noted three commercial airline accidents since 1994 in which the pilots showed lack of judgment, professionalism, and, in one accident, even basic piloting skills. He noted how in the past, airline pilots' skills were generally much higher because of the world-class training of military pilots from WW II, Korea, and Vietnam. He noted, "We are losing that pipeline of military pilots and will never see it again because big wars are hopefully something of the past, and many future military airplanes won't have pilots." He believes, therefore, that "the military pipeline of the past is gone for good."

To clarify the importance of the loss, he discussed some accidents that he believes illustrate "lack of professionalism and judgment," and "no stick-and-rudder skills." He stated that none of the noted accidents involved military-trained pilots. The FAA, he said, needs a much more robust way of putting people in the cockpit of commercial airliners. "What worked in the past will not work in the future because of the loss of military-trained pilots." The military, he noted, has shown that it has the type of clearing and training systems to determine if pilot applicants "have the right stuff. This is not to say that all military-trained pilots are better than civilian-trained pilots, because we have top-notch civilian trained pilots, too. The problem is that the two bell curves don't overlap; we need to bring the civilian bell curve up to where the military bell curve is. That is our challenge."



MARC MEETING DONATION LIST

ISASI Rudy Kapustin Memorial Scholarship
(In memory of all ISASI members who have died)

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But the vice chairman didn't speak only of the negative, he also spoke of accidents that produced demonstrations of "abundant professionalism," and in which teamwork, use of cockpit resource management, and piloting skills were top notch.

He next turned to criminalization of inadvertent error, noting that the "increasing tendency today is to punish."

Hart noted that too often the professionals caught up in the punishment craze are charged because of *inadvertent* error, not error caused by willful wrongdoing. He noted that he favors criminalization for intentional wrongdoing, such as coming to work drunk, but he emphasized his belief that criminal punishment of inadvertent error not only does *not* help improve safety of the system, but may actually subvert the safety of the system.

He said, "The threat of criminalization only creates silence in all reports of accidents. It also chills willingness to

s MARC Meeting

Richard Stone announces ISASI's scholarship winners. Below: Attendees fill plates from the buffet table.

participate in proactive information programs that have been so tremendously effective in enhancing aviation safety by collecting and analyzing large quantities of data to help identify precursors of problems that haven't yet occurred and to do something about them before the problems hurt anyone or bend any metal." The threat of criminalization is a global problem, he added.

In addressing prioritization, he said that the aviation industry's proactive information programs have increasingly enabled it to spot precursors involving things that haven't gone wrong yet. "In the past," he noted, "most improvements in safety came from things that went wrong, but that now most safety improvements are coming from things that could go wrong but that haven't yet gone wrong," alluding to findings of accident investigations for the past and advances in information technology in analyzing data for the present.

MARC President Schleede welcomes attendees.

Because the ever-enlarging safety pie consists less of things that have gone wrong, i.e., accidents and incidents in which the NTSB gets involved, and more of things that could go wrong, the NTSB must rethink the role that it must play to maintain its leadership in the continuously safer aviation industry. In addition, the entire industry must figure out how best to prioritize its scarce safety improvement resources, deciding which issues to address first and which to defer until later, because the pie of things that could go wrong is getting bigger, but the resources to address those issues are not generally increasing.

Other meeting events

Preceding the guest speaker, the 81 attendees enjoyed a lively "refreshment hour" and a superb buffet dinner that was followed by the call of winning door prize ticket holders. In all, 10 prizes were available from donors that included AirTran Airways; Southwest Airlines; the Air Line Pilots Association, International; Airbus Industries; RTI Group; the University of Southern California; Omega Travel; the National Air Traffic Controllers Association; and the Transportation Institute. Top prizes included round-trip tickets for two from AirTran and Southwest.

Ron Schleede, MARC president, welcomed all and urged participation in a special fund-raising challenge for the ISASI Rudy Kapustin Memorial Scholarship. He described the funding methods used for the scholarship, noting that contributions made in the U.S. to the fund were tax-deductible and that all funding comes from contributions. He emphasized that no member dues were used to fund the scholarship. He added that the largest fund-raiser is the spring MARC meeting.

He began the challenge with a $200 donation in the name of his deceased wife, Kathy, who "loved ISASI." Responses came quickly and unhesitatingly. The donation total reached $4,851. The winning challenge was a $601 donation by the Dallas-Ft Worth Regional Chapter. Other donors are listed in the adjacent sidebar.

Richard Stone, co-chair of the scholarship program, announced the 2011 winners who received an award of $2,000, on the basis of their excellent 1,000-word essay addressing "the challenges for air safety investigators." Awardees are Ainsley M. Robson from Embry-Riddle Aeronautical University in Miami and Daniel Scalese from the University of Southern California.

The MARC meeting is held in conjunction with the spring ISASI International Council meeting, which meets the next day. ISASI President Frank Del Gandio addressed the group and talked about the ISASI Reachout program. He said that 2,053 persons have been trained through the workshop-style training sessions. Of those attending, he said, "Many generally don't have the opportunity to get the same type of training that many of us have had. Reachout is cost free to attendees, and instruction is by ISASI volunteers." He also noted that much of the cost for any specific program is borne by the host-sponsoring entities of the area in which the workshop is conducted. ◆

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WHO'S WHO

Targeting Safety and Risk Management

(Who's Who is a brief profile prepared by the represented ISASI corporate member organization to provide a more thorough understanding of the organization's role and functions.—Editor)

Curt Lewis & Associates, LLC is an international firm headquartered in Arlington, Tex., with a Latin American office in Rio de Janeiro, Brazil. The firm is also globally sponsored by satellite representatives/partnerships in Chennai, India, and Calgary, Alberta, Canada. Curt Lewis & Associates is a multidiscipline technical and scientific consulting firm specializing in aviation and industrial safety, audits, training, and services.

The firm's expertise and specialties include safety management systems (SMS), aviation safety programs and training, airport safety programs and training, emergency response planning, accident investigation, aviation litigation support, auditing (compliance assessments/audits), human factors, security programs and training, quality and risk management programs and training, system safety, product safety, staff acquisition, and SMS software.

The Flight Safety Information newsletter and journals are a free service of Curt Lewis & Associates, LLC and are provided to more than 35,000 subscribers worldwide. Flight Safety Information (www.fsinfo.org) provides a free daily electronic newsletter on current topics concerning flight safety from around the world. The newsletter consists of article summaries from newspapers, websites, and other industry sources containing information on the latest accidents, incidents, recommendations, and industry information. The Flight Safety Information journal also produces periodical journals with a focus on current trends, technologies, and elements of safety.

Curt Lewis, P.E., CSP is currently the president/owner of Curt Lewis & Associates, LLC. He has been an ISASI member since 1988, is the past U.S. councillor/president for the U.S. ISASI Society, past president of the DFW ISASI Chapter, and is a Fellow with the Society. He retired from American Airlines after 17 years, serving as the head of flight and system safety. Additionally, he serves as an assistant professor at Embry-Riddle Aeronautical University (ERAU) and is the discipline chair for aviation safety.

He has more than 35 years of safety experience as a professional pilot, safety engineer/director, and air safety investigator. Lewis holds an airline transport pilot license (ATPL) and certified flight instructor certificate (ASMEL-I) and has more than 10,000 hours of flight experience. In addition, he has earned bachelor degrees in aeronautical engineering and physics and a masters degree in aviation and system safety. He is completing a Ph.D. in safety management.

Darwin Copsey is currently the vice president of operations and chief operating officer (COO) of Curt Lewis & Associates, LLC. He has held positions of increasing responsibility in safety management systems, accident investigation and reconstruction, program and project management, education and training, production and generation, simulation, and human resources. Copsey's corporate experience in the aviation field has been enhanced and recognized while serving in both the active and reserve military forces for 23 years. His experience as an aviator includes flight crew duties on both fixed-wing and rotary-wing aircraft in the military and commercial sectors. He currently holds multiple Federal Aviation Administration (FAA) certificates and licenses, including pilot, flight engineer, and airframe and powerplant (A&P). ◆