LAUNCH RISK ACCEPTABILITY: THE PUBLIC SPEAKS

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ABSTRACT

The perspective of those assuming risk has become increasingly important to launch agencies. The IAASS white paper "An ICAO for Space?" proposed four ultimate goals of any international regulatory framework. The first of these was to

> *"Ensure that citizens of all nations are equally protected from "unreasonable levels" of risk from over flight by missiles, launch vehicles and returning spacecraft"*

A key component of this concept is the issue of what is an "unreasonable level" of risk from the **perspective of those assuming the risk**.

1. BACKGROUND

The IAASS Working Group on "An ICAO for Space?" defined a number of launch and reentry safety issues. At present, each nation with space access capability and weapons testing needs determines independently what risk limits to other nations are acceptable. Risk measures vary significantly as do the space faring nations' criteria for acceptability. Moreover, risk acceptability is determined on a per launch basis. The concerns of the risk receiving parties are not directly addressed; risks to major foreign cities and countries are typically not part of the launch acceptability decisions in some countries.

In addition, no attempt is made to assess the overall annual risk to all parties from all launches and returning spacecraft flown by all space faring nations, let alone to obtain their informed consent to being subjected to such risks. If there is to be informed consent several important questions must be addressed:

What adverse outcomes are we measuring when we refer to risk? Quantification of risks is inconsistent among space faring nations. Some only quantify risks from planned jettisons while others perform comprehensive analyses to include malfunction scenarios. Many limit their analyses to inert debris; a few address inert and explosive debris, firebrands, and toxic emissions. Many protect against fatalities while neglecting lesser injuries

What risk measures should be used to assure protection against unreasonable levels of risk? A number of different risk measures have been used to protect the public. Some of these are designed to protect the maximally exposed individual, several are designed to protect against societal risk, still others are designed to protect assets or protect the public against large (many simultaneous injuries or large economic effects) losses.

What constitutes unreasonable levels of risk? U.S. studies have suggested that the tolerability of a given risk level is related to both the benefit derived by the risk taker and whether the risk is voluntary. If, as we have suggested, some measure of annual risk is the appropriate measure, some approach is needed to address the variation in benefits afforded to the affected parties.

2. RISK COMMUNICATION

U.S. National Ranges establish and implement processes that assure public and worker risk levels associated with launch operations are reviewed and approved at a proper authority level. Each Range or Launch Program normally assigns the responsibility of formally accepting and assuming liability for risk to the public and workforce to a specific individual. At most U.S. Department of Defense (DoD) ranges, this responsibility is assigned to the Range Commander. Other non DoD ranges may assign this responsibility to a Launching Agency (especially when flying under an FAA license) or the Facility Director. The generic term; "decision maker" will be used in this paper to describe this important position. The decision maker may be a civilian leader or member of the armed forces, and is ultimately responsible for accepting or rejecting risk associated with operations performed in their cognizant areas

To help fulfill this responsibility, organizations normally establish and maintain a Range Safety Office. This office works closely with the launch vehicle and payload communities, establishes and implements range safety policy and requirements, and advises the decision maker on matters associated with range safety risk. To help in maintaining consistent requirements and policies, and to establish a forum where multiple ranges can discuss and develop common solutions to technical issues, many US ranges participate as members of the Range Commanders Council (RCC). This organization has representation from all agencies of the US DoD, including the Air Force, Army, Navy, NASA and the FAA. Among other responsibilities, the RCC is tasked with developing and maintaining commonality standards on range safety topics such as flight termination systems, risk criteria, unmanned air vehicles, global positioning, and inertial measurements tracking. Most ranges consider these standards the basis for locally established range safety requirements, including acceptable risk criteria.

The Federal Aviation Administration (FAA) regulates public safety of commercially licensed launches within the U.S., and U.S. entities launching somewhere other than a U.S. range Since most US commercial launches take place at federal ranges, the FAA and US ranges have teamed to develop common range safety standards. These common standards help to streamline approval of operations by avoiding over regulation and duplication, and sometimes confliction of requirements. The FAA also performed baseline assessments of various federal launch ranges to assess the adequacy of the range services. These evaluations resulted in defining federal launch ranges for which a launch applicant did not need to demonstrate the adequacy of the range services.

Due to the nature, complexity, and sometimes the classification of DoD or large government activities, the federal range decision maker is usually granted ultimate responsibility for accepting range safety risk associated with government launches or landings. The decision maker is not required to obtain public or representative approval when accepting elevated risk for areas within or exterior to government property. That being said, high emphasis is placed on maintaining a policy of not exposing the general public to "a risk level greater than the background risk in comparable involuntary activities." [1] Most range commanders, by requirement, can only accept risks above established baselines on the basis of national need. [2] The process associated with completing Environmental Assessments may solicit public opinion on the risks associated with range operations.

In addition to the safety requirements developed and implemented by the ranges, some range users, such as NASA, have developed and implemented independent range safety requirements, and associated processes for acceptance of public safety risk. These processes are considered in addition to range processes and do not substitute for or remove any authority from the range or decision maker. All parties must be "GO" for a launch to proceed.

2.1. Divulging the risk numbers

The communication of risk can prove to be complicated and difficult, but is considered a very important, if not the most important step of the risk management process. Communicating risk numbers requires mastering many elements, including the presentation of quantitative results compared to established criteria, understanding and explaining the uncertainty associated with the quantitative results, and addressing issues of particular concern to the decision maker.

Most ranges follow a similar process for risk communication. When a range user approaches the range with a specific concept or design to be tested or launched, the range responds with a statement of capability, essentially clearing the way for more detailed technical discussions. Range Safety and the range user then start a detailed tailoring process to identify agreed upon safety requirements and to identify potentially equivalent ways to meet requirements. When this process is complete, the set of tailored requirements is presented to the decision maker. The decision maker is responsible for accepting or disapproving any identified design or process that deviates from the baseline requirements and that may result in elevated range safety risk.

Following acceptance, the range user is responsible for implementing and complying with all tailored requirements. If deviations or exceptions are realized during the operations processing phase, the user may request a waiver to a specific requirement. The request contains justification to continue the operation with the identified deficiency and usually includes a get well plan and statements addressing the perceived increase in risk above baseline (residual risk) if any. The range safety office is then responsible to review the waiver request, perform a risk assessment, and provide a recommendation to the decision maker. It is then up to the decision maker to accept the residual risk, request additional mitigation efforts, or disapprove the waiver request.

2.1.1. "We are the safety professionals; don't say anything."

Balancing the amount of communication provided to the decision maker and those potentially hazarded by the risk can prove difficult. To determine the adequacy of a launch vehicle from a safety perspective, analysts routinely compare analyses results to documented standards or criteria. When common practices result in unfavorable results, a safety analyst may review the process and modify assumptions deemed overly conservative. The analyst then has to decide whether the change to standard practice should be presented to the decision maker. Many factors play into this decision; "How much more effort will be required to properly explain the process?", "Will the decision maker understand what I am trying to convey?", "Will a presentation in front of a large audience be required?", "Will an opposing view be presented?" and the list goes on. As can be seen, it is usually easier for the analyst to document the theory or assumption and move on without communicating the process change. Although usually done in good conscience, analysts may fail to communicate changes in process to the proper authority levels.

Liability must also be considered when deciding what is presented to the decision maker. The "informed decision" principle is used in tort claims against the US government, protecting officials from court system second-guessing in determining the acceptability of operational risks. However, a key test under this protection requires the decision maker to be fully advised and informed of the known risks. Failure to do so can result in increased liability of the U.S. government and/or the decision maker.

A way to foster proper communication habits within the organization is to create an environment of trust and open communication. Management sometimes overlooks the pressures realized by some analysts when having to present technically challenging ideas or differing opinions to groups or higher levels of authority. Managers should ensure they are approachable when potentially contentious issues arise.

2.1.2. "Communicate maximum individual risk allowable to range users selectively"

In the early development phases of the U.S. ranges, non disclosure of criteria used to determine launch vehicle safety adequacy was common. Without a clear understanding of minimum requirements, some safety offices believed range users would develop safer, less risky systems by not designing to a minimum set of standards. By not communicating "acceptable" criteria, they believed range users were more prone to design to a reasonable or higher level of safety. Ranges also believed this practice provided them with an advantage when requesting or requiring design changes or additional hazard mitigation, because an argument could not be made by the range user concerning compliance with minimum design standards. This practice often led to expensive and time consuming re-designs, frustrated range users, and the very subjective, inconsistent approach to launch safety approval.

Today, due to a number of factors, ranges have accepted, and found benefit in policy that requires the full disclosure of acceptable risk criteria and a set of minimum design requirements. Both the range and range user benefit from such a set of safety design and acceptable risk requirements. The range is able to enforce fair, consistent, defendable requirements while the range user has an upfront understanding of design expectations, making the approval process more streamlined and cost effective.

2.1.3. Collective and individual risk policy

Many local range safety requirement documents contain acceptable criteria for both collective and individual risk. Most of the documents develop acceptable criteria based on RCC-321[1] (See Fig. 1), which defines consensus standards for range risk management processes and acceptable risk criteria. Current policy at most ranges require either the launch user or the range to calculate collective and individual risk from hazards associated with the operation, and compare the results to acceptable criteria. Prior to starting the operation, all residual risk is presented and either accepted or disapproved by the decision maker. If risk is above acceptable criteria, the project team will first attempt to reduce risk below acceptable levels, but may ultimately request a waiver from the regulating authority.

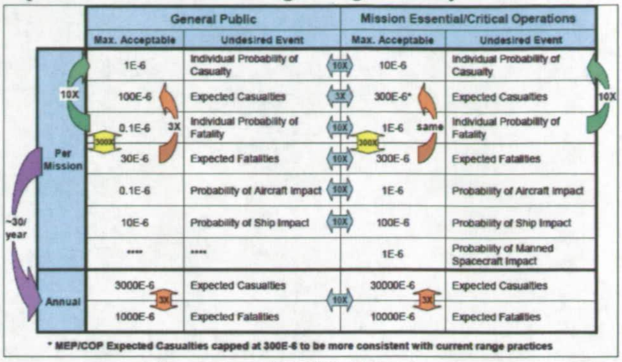

Figure 1. RCC 321 Criteria

An alarming trend surfacing within some of the range safety community is the justification of a failed test or lack of a specific safety system based purely on a calculated risk number. Two methods have traditionally been used concurrently to limit public safety risk; the use of a highly reliable range safety system (commonly referred to as a Flight Termination System (FTS)), and a flight safety analysis to ensure calculated risks are within acceptable criteria. Initial emphasis has always been on hazard containment and control. Risk analysis, with its many modeling and data uncertainties, is used to provide assurance that the risk is small and the primary controls are adequate. The evaluation of launch vehicle safety should always be based on both of these principles.

2.1.4. The Carnegie Mellon study

Fischhoff [3] describes four types of specialists needed for effective communication within organizations. They include:

1. Subject matter specialists, who can identify the processes creating, and controlling risks (and benefits).
2. Risk and decision analysts, who can estimate the risks (and benefits) most pertinent to decision makers (based on subject matter specialists' knowledge)
3. Behavioral scientists, who can assess decision makers' beliefs and goals, guide the formulation of communications, and evaluate their success.
4. Communication practitioners, who can manage communications products and channels, getting messages to audiences and feedback in return.

Applying creative license, one may observe the ranges applying this philosophy in their own way, but with potentially serious limitations. In the case of the DoD ranges, the decision maker is considered to be the Commander, so the need for behavior scientists and communication practitioners are different, and may even be diminished. However, like many other organizations, subject matter experts and risk analysts develop and deliver presentations to the decision maker based on technical information and, although usually innocent, a potentially narrow view of the issue. In addition, these individuals may or may not understand the issues important to the decision maker and sometimes use the presentation to advance or advertise a certain agenda.

Fischhoff suggests the following when trying to determine what to convey:

1 *Complete mental models, by bridging the gaps between expert and lay mental models*. That could mean adding missing concepts, correcting mistakes, strengthening correct beliefs, and de-emphasizing peripheral ones.

2. *Ensure appropriate confidence in beliefs*. The most dangerous beliefs are those held with too great or too little confidence. The appropriateness of confidence can be assessed by comparing judged probabilities of being correct with actual ones. Then focus communication on cases where overconfidence could cause poor choices or under-confidence could prevent sound ones. Routinely communicating how well facts are known might improve the appropriateness of recipients' confidence.

3. *Provide information in order of its expected impact on decisions*. Value-of-information analysis determines a fact's expected contribution to decision outcomes. Although nothing should be hidden, communications should get these few facts across.

3. COOPERATION AND CONFRONTATION

Space lift operations can pose a threat during prelaunch processing, launch and ascent to orbit and return from orbit or space. Return from orbit is further divided into random re-entry, planned controlled re-entry and planned uncontrolled re-entry. Random re-entry can place any location at risk within the overflown latitudes. Planned re-entries affect more confined regions; planned controlled re-entries can direct hazards away from populations and valuable assets. Random re-entries for larger objects transform, as an orbit decays and the objects are more closely tracked, into a more planned, but possibly uncontrollable re-entry. . The international track record varies significantly among these phases of operation.

3.1. Launch and Ascent

An important consideration in siting a launch complex is adequate control of surrounding lands to minimize current risks to the public from processing and launch operations, and to manage foreseeable future risks. Support from the surrounding communities and their government is a key to implementation. Outside of the immediate launch area, management of risks by controlling land use is more difficult.

In the early 1990's, the State of Hawaii invested substantial sums of money for planning and environmental studies to support a proposed development of a Palima Point Space Launch Complex. The launch site was shown to be versatile, capable of supporting missions ranging from near equatorial orbits through polar orbits and accommodating launch vehicles with a heavy lift capacity (Delta II). The high quality technical planning did not offset the failure to involve the local population. Without any recognition of local benefits, stories in the local paper about the potential for catastrophic toxic spills outside the local café quickly put an end to this project.

Contrast this experience with Spaceport America in New Mexico. This inland facility spent many years developing a broad support base from the local towns up through the state government. Enthusiasm for the effort is directly related to the expectation of long term economic benefits to the region.

Vandenberg Air Force Base supports polar inclination/orbit space lift operations. Ranchers occupying in holdings within the base consider it an opportunity to show their patriotic support for their country by leaving their homes during potentially hazardous operations.

The Baikonur Cosmodrome was built during the Soviet rule. Later with the breakup of the USSR, Russia signed an agreement with Kazakhstan to rent the facilities until 2050. The rental fee has been a continuing source of dispute between Russia and Kazakhstan.

Thus, it should be no surprise that when there were a series of launch failures of the Proton launch vehicle, Kazakhstan was sensitive to the Russian response to the failures. In July 1999, after failure of a Proton launcher, a 200 kg segment fell into the backyard of a villager on the steppe of the northern Kazakh region of Karkaralinsk. BBC reported that the Kazkh government was angry with Russia [4]. In October of that same year, after a similar explosion, Russia responded promptly to the Kazakh prime minister's request to assess the potential for environmental damage and to compensate Kazakhstan for any environmental damages. This prompt response resulted an expression of satisfaction by the Kazakh government [5].

3.2. Re-entry

Truly random re-entry affords minimal risk management opportunities. At the design stage, engineers can consider the potential impact of promoting re-entry thermal demise. Moreover, there is a growing literature that addresses these risks.

The uncontrolled re-entry of large objects, such as boosters and spacecraft, hazard relatively broad, but more well-defined regions. Objects of concern range from large, well-publicized spacecraft, such as the Hubble Space Telescope and the Russian Mir Space Station, to more covert spacecraft such as the Russian RORSAT COSMOS satellites. Key elements that have occurred in response to uncontrolled re-entries have typically been detection, tracking and narrowing the region hazarded, verification of key facts with the spacecraft owner, development of emergency response plan, and emergency response communication.

As the Mir Space Station approached the end of its life, the Russian Space Agency was able to focus their re-entry calculations. They planned to initiate re-entry with a series of braking maneuvers designed to produce a splashdown in an area of the Pacific midway between New Zealand and Chile. Nevertheless, the Russians provided advance planning and coordination information to nations that could potentially be affected from their Ministry of Foreign Affairs and their Aviation and Space Agency. Australia was notified as part of the communication of the remote possibility of Mir debris impacting on Australia. Australia developed an information tracking system, a Mir National Warning Group, and established the ground work for activating the Commonwealth Government Disaster Response Plan in case of on land debris impacts. Warnings were posted to pilots and mariners of areas expected to be hazarded. Finally, press briefings were issued by the Australian Emergency Management Agency. The potentially affected public was, thus, well-informed, even though ultimately on March 23, 2001 the Mir debris impacted, as expected, in the ocean [6].

The Mir success provided a contrast to earlier re-entries taking advantage of its controlled re-entry and using early and continued dissemination of planning information to the international community. In July 1979, Skylab re-entered showering the area southeast of Perth, Australia with pieces of debris [7]. No one was injured nor was there property damage. Although NASA had originally planned to retrieve Skylab in the Space Shuttle's cargo bay or to boost it to higher orbit, these solutions were not available in time to support this approach. The situation was aggravated by the increased atmospheric drag from the approaching solar maximum. NASA engaged in a number of ingenious approaches in an attempt to maintain Skylab in orbit long enough for it to be rescued. Ultimately, it became apparent that rescue was impossible. NASA initiated a coordinated effort involving key NASA centers, the FAA, NORAD, and the U.S. State and Defense Departments to coordinate re-entry predictions, risk predictions, dissemination of information and emergency preparedness. Major challenges involved drag uncertainty and uncertainty in the progressive breakup of the cluster.

Much of the media attention focussed on the Skylab arose in reaction to the January 24, 1978 uncontrolled re-entry of the Russian RORSAT Cosmos 954. In late 1977, U.S. tracking radars reportedly observed an unusual decay of the Cosmos 954 orbit. The U.S. formed an interagency team to evaluate the situation and develop an appropriate contingency plan. Implementation was complicated by the need to confirm with the Soviets information regarding their surveillance satellite. After it was confirmed that the satellite contained a small reactor for its payload, the U.S. began to prepare for its re-entry [8], [9]. This included communication with other nations, the U.S. Congress, and the Federal Preparedness Agency. After the satellite crashed in the Northwest Territories, Canada, a joint American-Canadian team surveyed the area, some 48,000 square miles, by foot and by air in an attempt to recover radioactive material. The Canadian Government billed the Soviet Union for over $6 million for expenses and future unpredicted expenses. The Soviet Union eventually paid Canada $3 million in settlement [10].

At 8:00 A.M. on February 1, 2003 the NASA Mission Control Center, having completed their safety checklist review, determined that the Space Shuttle Orbiter, *Columbia*, was "GO" for de-orbit burn leading to a planned controlled re-entry. The *Columbia* Accident Investigation Board reconstructed both the train of observables and characteristics of the accident [11]. Among the earliest signs of Columbia's shedding debris were noticeable bright streaks in *Columbia*'s luminescent trail beginning sometime after crossing the California coast. Nevertheless, it was not until shortly after the scheduled landing in Florida approximately 9:15 EST that NASA, recognizing that *Columbia* had been destroyed during re-entry, and that there were no survivors, initiated its Contingency Action Plan. NASA immediately initiated warnings to the public of the hazards associated with certain pieces of debris from toxic and explosive materials, and initiated a massive search plan to identify impact locations and safely recover the debris. No one was injured by the falling debris and property damage was minimal, largely because of the low population density in the impact area.

In none of these cases, were the risks assumed with consent of those on whom they were imposed. The uncontrolled re-entry risks demonstrated a need for an evolution in risk communication and emergency response. The Columbia controlled re-entry failure brought about several major changes in the U.S. NASA developed and disseminated a public risk acceptability policy for launch and re-entry of space vehicles. [12] To support implementation of these policies, NASA has directly and, through its contractors, developed tools for quantifying third party risks. The FAA has recognized the need to clear the air space volume potentially affected by a failing returning spacecraft and, with coordination from NASA, has initiated a program to divert traffic from the hazard area in the case of an accident.

4. INTERNATIONAL ISSUES

The previous anecdotes illustrate several evolving issues associated with the growing numbers of space faring nations and launches. The issues arise from the needs for informed consent of those assuming the risk and mechanisms to communicate and manage hazards in an emergency. Important elements include risk assessment, risk communication, risk management, risk acceptance, and emergency preparedness and response. How these issues need to be approached is directly related to the reliability of space lift vehicles. For the foreseeable future, it is reasonable to assume that launch vehicle improvements may significantly enhance overall performance and reduce the cost of access to space. However, partially due to the limited number of launches, these improvements are not expected to have a significant affect on reliability. It is assumed the level of reliability associated with commercial aircraft will not be soon achieved. This will result in a growing number of launches, re-entries and over flights of foreign territory by low reliability boosters.

The nature of the response required for these issues varies with risk levels, number of involved participants, and the associated political relationships. Launch area risks usually are the most well-defined, involving, at most, the launching nation and the host nation usually placing relatively small numbers of people at risk. Although hazard areas associated with a full malfunctioning space booster are larger than those from an upper stage, the relative predictability of the area that may be affected, and its modest geographical extent facilitate risk management. Frequently, the region in the launch area is within the jurisdiction of the launching country. When this is so, it renders the compliance with local regulations and interagency cooperation easier. Increasingly, however, the launching nation and the launch site are not the same. Russia has faced this situation with their Baikonur Cosmodrome and both Russia and other European nations face that situation with launches from Kourou.

As a space booster proceeds downrange and increases speed, small changes in the velocity vector result in large changes in the location of areas hazarded by a malfunction, increasing the region potentially hazarded by a failure and the number of people potentially at risk. This is somewhat offset, from a risk management perspective, by the smaller casualty area (area in which people of property may be hazarded) associated with the failed vehicle, the increased time between an accident, and the time people or assets are at risk. Similar factors apply for downrange over flight and over flight during re-entry.

Informed consent and emergency preparedness are considerations throughout flight from launch to re-entry. The extended launch area will likely involve citizens of the launching states and the host state. With a single launching agency, the processes and procedures for quantifying risks may be expected to be internally consistent. The challenge will be working with emergency preparedness agencies, local governments, and, as required, addressing the bilateral agreements needed when the launching nation and the host nation are different.

With multiple launching agencies or multiple launching nations, the problem becomes more complex. Each is likely to have its own procedures for quantifying and managing risks. Each is, moreover, likely to regard significant aspects of this process in a proprietary manner creating challenges for assessing the annual risks to those in the launch area and to structuring appropriate emergency response processes.

Outside of the immediate launch area, the situation becomes more complex. Risk communication is complicated by the larger area at risk from any accident, by the involvement of multiple nations, and contribution of multiple launch sites, agencies, and launching nations to the annual risk. Fig. 2 shows an example of the large downrange region potentially influenced by two U.S. launch sites. Typically, risk contributors in the downrange region and for re-entry extend to include multiple agencies, launch sites, and launching nations complicating issues of annual risk assessment, risk management and risk communication. An example of the added complications is the challenge of protecting ships and aircraft over international waters. Publishing warning notices to either ships or aircraft over broad ocean areas is of limited effectiveness without surveillance.

Surveillance on large areas, distant from land is costly. Currently, limited systems are in place to divert aircraft or ships after an accident. Neither is there any international system in place to respond when a launching nation recognizes that danger is imminent.

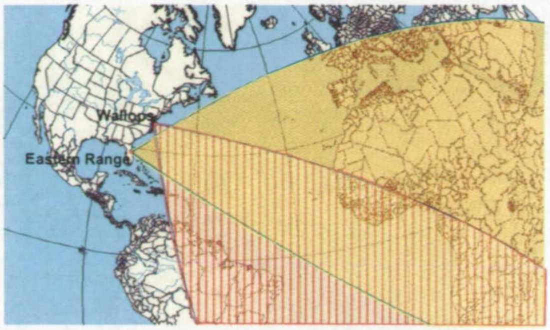

Figure 2. Over flight from multiple ranges

5. PROTOTYPE APPROACH

The following concepts illustrate two innovations that may be more broadly applicable to address the issues of informed consent by risk takers and emergency preparedness by space faring nations.

5.1. ER and Brevard County Emergency Response Partnership

The relationship between the Eastern Range Safety Office and The Brevard County Office of Emergency Management can be seen as an example of a successful risk communication/mitigation partnership. Although not directly involved with launch risk decision process for the reasons discussed in Section 2, Brevard County takes an active role in working with the range safety office in establishing proactive mitigation techniques implemented in the event of a launch accident.

On a yearly basis, the range safety office meets with the Brevard County Emergency Management personnel, and discusses new launch vehicles, hazard mitigation, and response actions. These discussions provide first responders with the knowledge required to react to such emergencies. It also provides insight into the launch business and presents, credible, although highly unlikely, scenarios to the responders. This communication is very helpful to both organizations in that it provides a forum to discuss actual events and not rely on "standard" emergency protocols for response.

During the launch count down, the county activates the Brevard Emergency Operations Center (BEOC and provides a representative to the Morrell Operations Center (MOC). The MOC serves as the Eastern Range control center for launches. The county representative is provided a console adjacent to the risk analysts and provides real-time information to the BEOC in preparation for emergency response.

5.1.1. Reverse 911

A very useful tool being implemented at some ranges is the reverse 911 system. The Eastern Range (ER) and The Brevard County Office of Emergency Management have implemented such a system to help mitigate hazards associated with a launch anomaly. As provided real time during a launch, the ER Toxic Risk Engineer (TRE) advises the county representative of potential worst case toxic plumes that may result in the event of a launch anomaly. If the event occurs, the county is ready to activate the reverse 911 system with pre recorded announcements advising the public of the accident and what sheltering or mitigation actions to take. As real time updates are received, the areas being called can be quickly changed with different instructions, if appropriate. The system provides the ability to contact every household (with wired telephone service) within the area the operator selects on a common GIS map computer screen. The system can also be used for advising the populace on a variety of other launch related hazards and weather conditions (tornadoes, flooding, etc) and potential criminal activity (kidnapping alerts etc) and provides an outstanding service to the community. Implementation of such a system provides a powerful communication tool and has been proven to be very useful part of an overall launch hazard mitigation process.

5.2. Spaceflight Management Program

A detailed aircraft risk analysis, funded by the FAA, used the records of aircraft activity at the time of the *Columbia* accident, and found that the probability of an impact by *Columbia* debris to commercial aircraft in the vicinity was at least one in a thousand, and the chance of an impact to general aviation was at least one in a hundred. [13] After FAA executives were briefed about the potential for aircraft impacts during the *Columbia* accident the FAA began to investigate a decision support tool to better manage the interface of space and air traffic in the future. The FAA has initiated the Spaceflight Management Program (SMP) to better coordinate space vehicle operations with air traffic. As part of the SMP, tools and procedures are being developed to prepare for and then mitigate the risks to aircraft from space vehicle accidents. These tools will provide air traffic managers situational awareness of space traffic in a routine manner. In addition, in real time, if there is an accident, one tool will compute the air space hazarded by debris using models of breakup and real-time data from the space vehicle. The resulting information will be forwarded to the FAA's Enhanced Traffic Management System (ETMS) as Traffic Flow Management (TFM) areas, which initiate the process of air traffic controllers directing aircraft away from the hazard in the time between the accident and the time the debris falls to aircraft altitudes. [14] SMP would treat the potential debris hazard like an area of severe weather, and would provide conflict advisories and recommend routes to safely and efficiently direct aircraft around the hazard area.

6. IMPLICATIONS FOR THE INTERNATIONAL SPACE COMMUNITY

A prerequisite for *informed consent* is a consistent means of quantifying and expressing risk from launch and re-entry operations. Presentations at both the first and the second IAASS conferences demonstrated the diversity of risk quantification methods, risk measures, and risk acceptability standards employed by space faring nations. The U.S. FAA has drafted standards addressing these issues. One approach to standardization would be to use the FAA effort as the point of departure for a working group including the major international space agencies. These previous efforts will provide a foundation for characterizing sound methodologies for quantifying mission risks.

It will then be necessary for the group to shift their perspective from that of a space faring nation to that of a risk taking nation. Measures and procedures will need to be formulated from the existing processes to translate the risks into measures meaningful to those assuming the risks, such as maximum annual individual risk or annual societal risk. The societal risk measures will need to define appropriate geographical regions for aggregating risks. One might assume that societal risk need only addressed at the level of affected nations. This would, however, lead to the anomaly that it might be acceptable to subject several small nations to a level of risk that would be rejected if imposed on a large nation of their combined geographical area.

Other important administrative issues that must be addressed in such a system include

- Defining a system and agency to track risk reporting for completeness and consistency
- Development of a dissemination plan defining the organizations who should be the recipients of the risk computations and what information each should receive
- Defining processes and procedures to address obtaining national risk acceptance by affected nations
- Defining processes to address risk mitigations when the risk to some region is excessive. This may be particularly challenging since the risk may result from multiple launches from different launch sites

The second major gap is a system for *emergency preparedness, notification and response* to booster malfunctions and malfunctions of returning spacecraft.

- Notification and response time may be extremely limited. The available time must be used to identify and evaluate the potential hazard, to notify aircraft and ships to avoid the expected hazard zone, to develop and disseminate public advisories for sheltering, and to mobilize post disaster response. Thus, a high priority is the development of an *emergency response plan*. Space faring nations should develop a means of sharing "lessons learned" defining effective plans.
- *Implementation:* International protocols need to be developed for effectively communicating hazard areas in international waters and airspace. Cooperative agreements are needed to overcome the difficulties in patrolling waters and airspace at a large distance from land.

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Acceptable Risks:

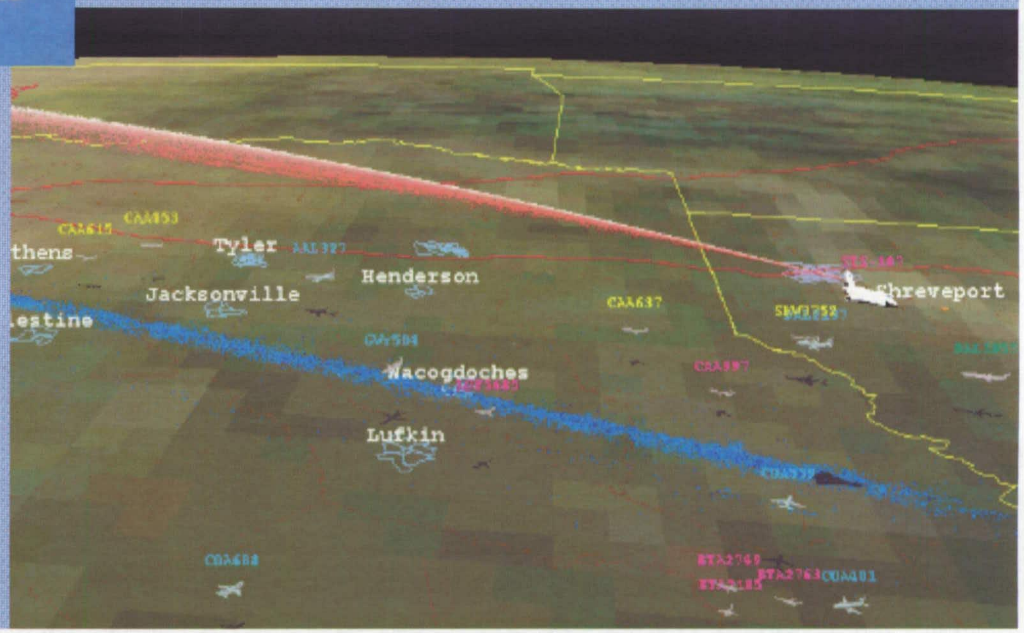
The Public Speaks

Third International Conference

International Association for the Advancement of Space Safety

October 2008

J. Haber & R. Lamoreaux



2007: IAASS Working Group proposed four goals for Space Safety.

The first was to:

"Ensure that citizens of all nations are equally protected from "unreasonable levels" of risk from over flight by missiles, launch vehicles and returning spacecraft"

It is understood that protection should address all hazardous mechanisms from normal flights and malfunctions.

Outline

- Have we achieved the goal already?
- What progress have we made?
- What issues must be addressed?
- Recommendations to the Space Faring Community

Outline

- **Have we achieved the goal already?**
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Checklist: Achieved the Goal?

- "Unreasonableness" is a matter of perception. Risk takers must be part of the process.
- We need to speak the "same language" when talking about risk.
  - What level (s) of injury and damage do we mean?
    - (fatality, casualties, severe injuries, minor injuries, etc.)
  - What are our measure (s) of risk?
    - (maximum individual risk, collective risk / societal risk, catastrophic risk, impacts to critical assets)
  - What threats must be addressed?
    - Planned and malfunctions
    - Inert debris, explosions, fire, toxics
- We need methods to consistently quantify risk and aggregate the risk over all launches, launch sites, and launching nations.

Outline

- Have we achieved the goal already?
- **What progress have we made?**
- What happens if we do not?
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- Recommendations to the Space Faring Community

We've made some progress! (but have a long way to go):

- As a community, space faring nations have made some progress:
  - Through the IAASS and other platforms we are
    - Sharing our methods for quantifying launch and reentry risk
    - Sharing our risk management methods
    - Sharing our standards for acceptable risk
  - In the USA, we have been developing consensus standards for risk quantification and risk acceptability among our ranges.
  - ESA and the USA have made initial steps to exploring each other's risk quantification and risk acceptability standards.
  - We have begun asking the critical questions to identify present and future issues.

RCC 321-07 Achievements

- U.S. acceptable risk guidelines for launch by launch
  - Societal risk
  - Individual risk
  - Protection of ships and aircraft
- Rationale for acceptable risk criteria
- Hazard thresholds
- Guidance for modeling launch risks from
  - Inert and explosive debris
  - Toxic exhaust and combustion products
  - Distant focusing overpressure
  - Radiation hazards

Risk Communications

- The launch authority and his safety representatives
  - Evaluate the risk
  - Launch authority: National need -- accept above baseline risks
- Communication of acceptable levels of risk
  - General policy is public: RCC 321-07
  - Major evolution from early policy of non-disclosure of acceptable levels outside of range safety offices
- Evolving issues
  - Published acceptability levels encourage launch agencies to "push the envelope" instead of minimizing risk
  - When and what to communicate of risk analyses of particular missions

Outline

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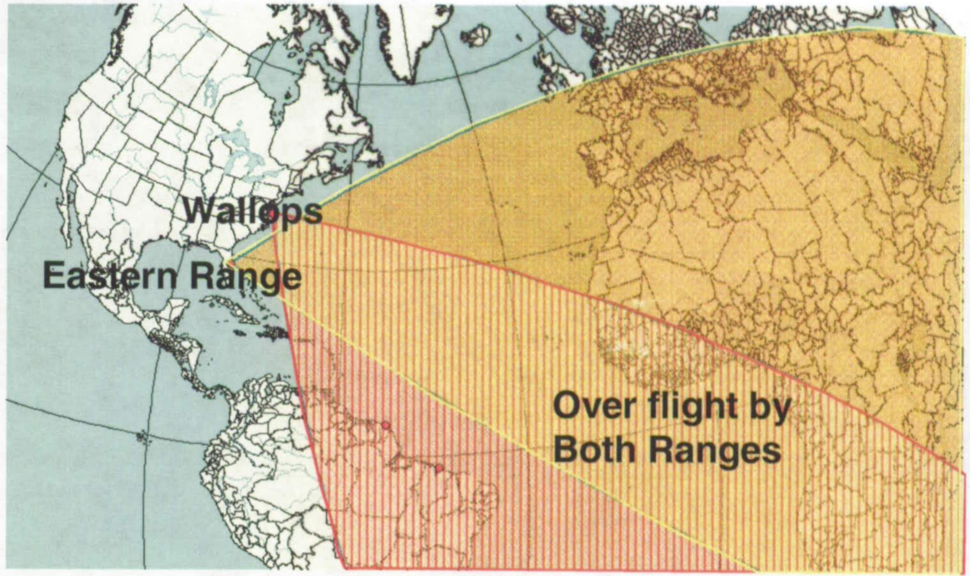
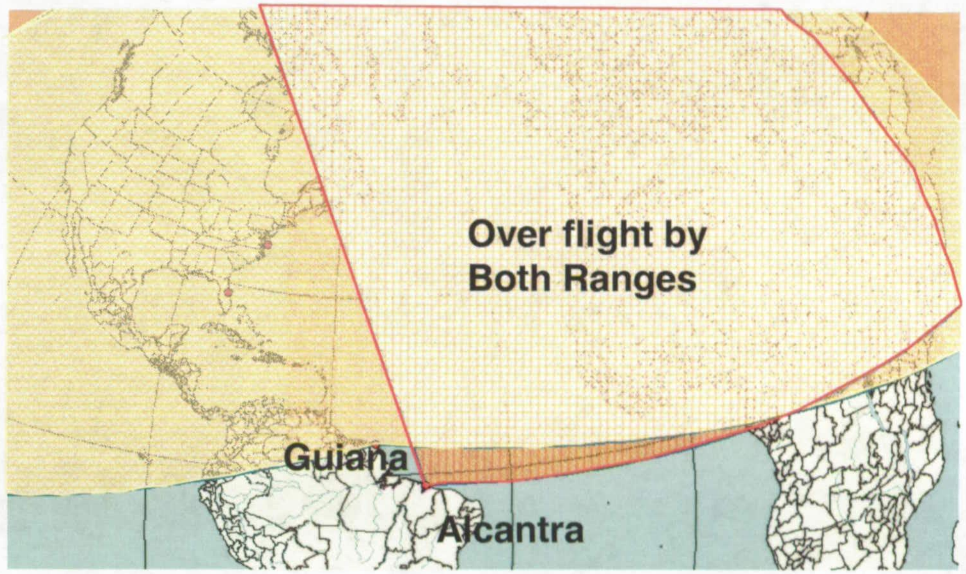
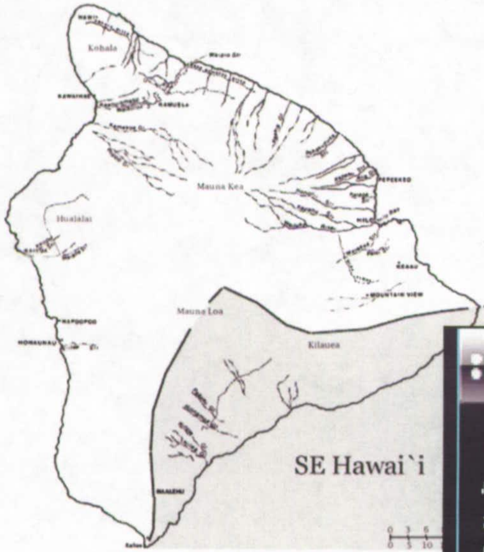
Some challenges

- Launch acceptability is typically treated on a **per launch** basis.
- Risk acceptability is generally understood on an **annual basis**.
- Multiple launch sites from different nations can hazard the same areas.
- Risk acceptability is linked to perceived benefits and choice. Perceived benefits from different launches will vary; choices may depend on relationships between the launching nation and the over flown nation.
- How should allowable risks be allocated back to the space faring nations?
- Implementation and monitoring?
- Emergency preparedness and response





Involvement, Risk Communication, and Acceptance



- In the US, failure to obtain timely involvement of the public resulted in the demise of the proposed Hawaiian Spaceport.
- Spaceport America is enthusiastically supported by its neighbors.

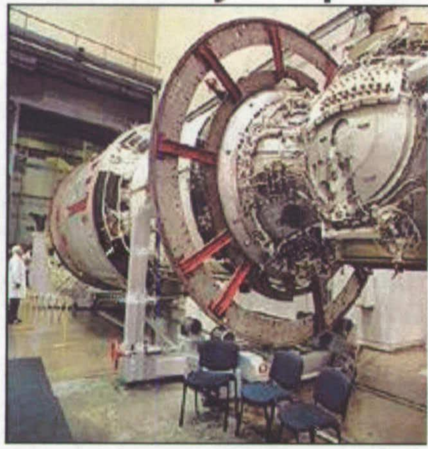
BBC NEWS

News in Audio | News in Video | Newyddion | Новости | Noticias

Wednesday, July 7, 1999 Published at 11:02 GMT 12:02 UK

Sci/Tech

Proton worry for space station



The ISS service module is due to go up in November

The next phase of the multi-billion-dollar Inte
(ISS) hangs on the outcome of an investigati
Proton-K rocket failure at the Baikonur Cosmo

The rocket, carrying a
communications satel
launch scattering deb

In a statement on local TV, picked up by BBC Monitoring, the Kazakh government was said to be angry with Russia because of the accident. The Khabar TV presenter said the ban on further launches would stay in place "until all issues related to the catastrophe are investigated and the material damages inflicted on Kazakhstan are established."

ISS service module

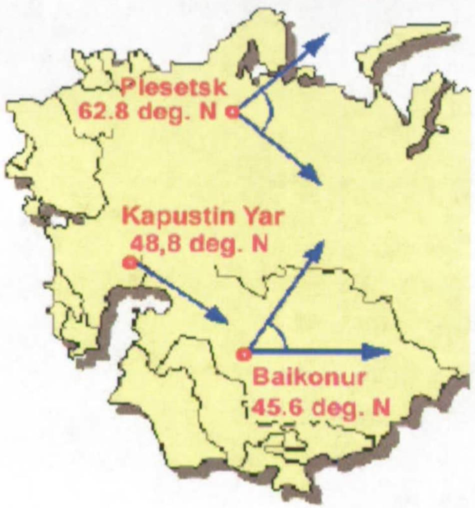
Part of the Proton launcher, weighing some 200 kilograms (440 lbs), fell into the backyard of a villager on the steppe of the northern Kazakh region of Karkaralinsk.

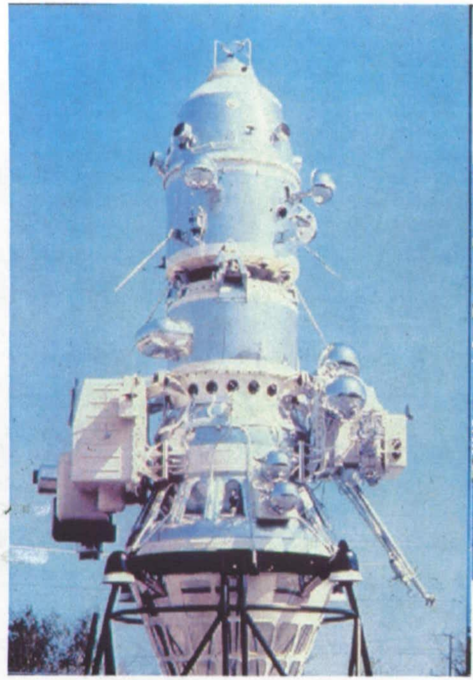
There were no victims, although a woman and her son were at home when the rocket part fell from the sky, the TV said.

Relati
and th
have
Russ
Baiko
is rep
rent.

Baikonur was established during the time of the Soviet Union. Following its breakup, Russia and Kazakhstan negotiated terms for the use of the facility.

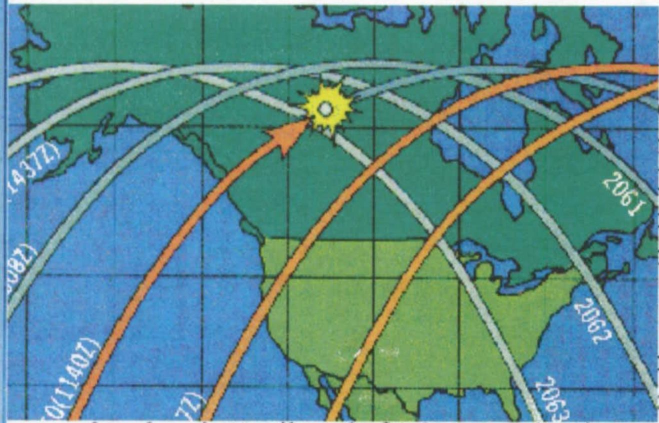
Nevertheless, the need for on-going balance between the risk takers and the Russian space program offers challenges.





Cosmos 954

From Wikipedia, the free encyclopedia



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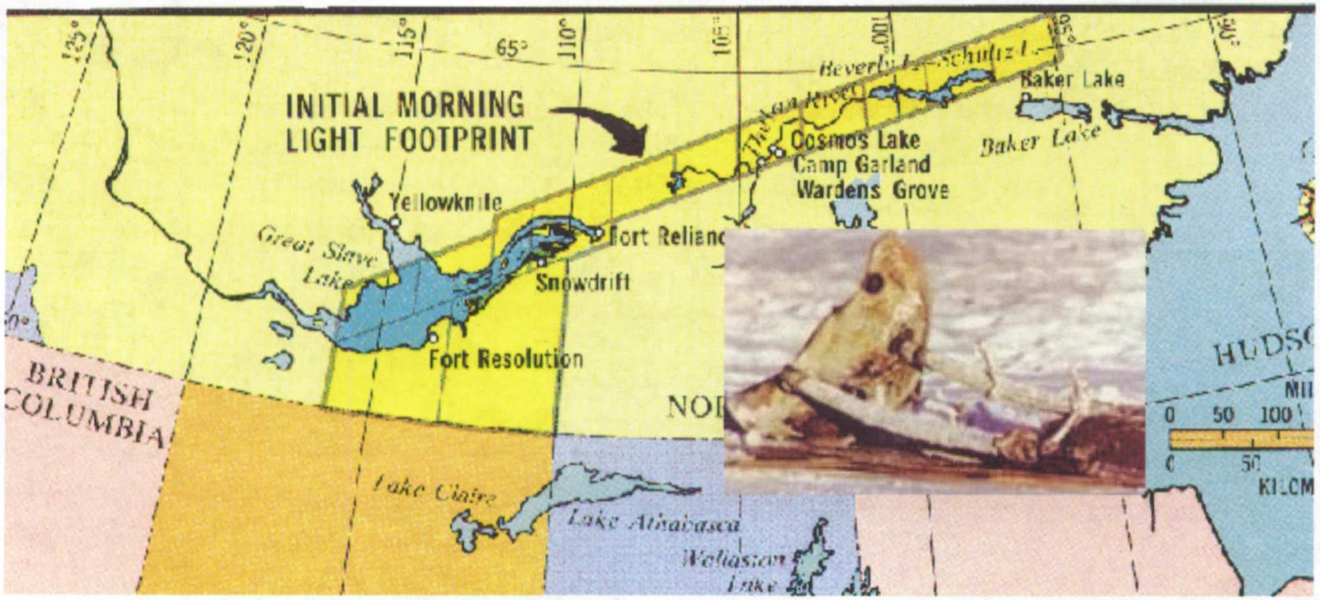
...oot and air until the spring ice breakup in April made further searches impractical. They were ultimately able to recover 12 larger pieces of the satellite. These pieces displayed radioactivity of up to 1.1 sieverts per hour, yet they only comprised an estimated 1% of the fuel. For these recovery efforts, the Canadian Government billed the Soviet Union $6,041,174.70 for actual expenses and additional compensation for future unpredicted expenses; the U.S.S.R. eventually paid the sum of 3 million dollars.

Re-entry

Re-entry risks are particularly challenging.

The *communications* and *emergency response* issues are magnified when it is an uncontrolled re-entry.



Emergency Management Australia Update on Re-entry of Russian Mir Space Station 03-16-2001

• 0

STATUS REPORT
Date Released: Friday
Source: Emergency Ma

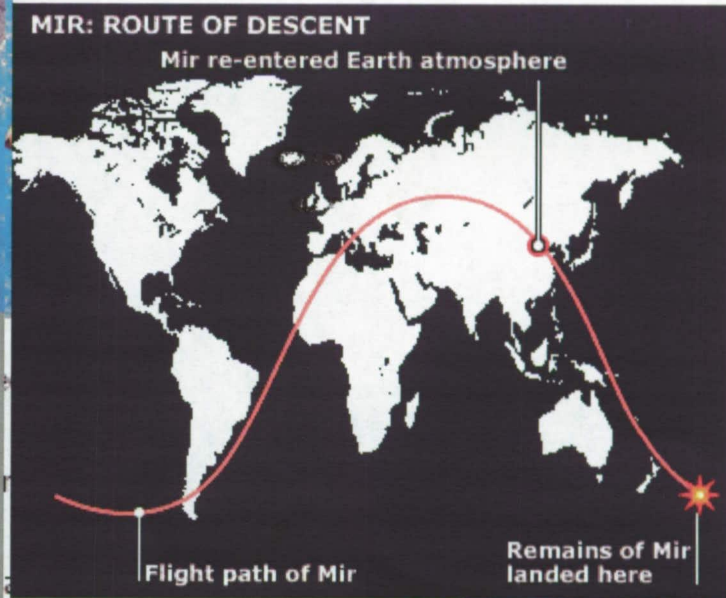
Emergency Management Austr
Territory

MEDIA ENQUIRIES

Brian Flanagan
EMA Media Liaison
Mobile: 0409 489 344

MIR Re-entry

Controlled MIR re-entry provided an opportunity for effective communications and emergency and emergency preparedness.

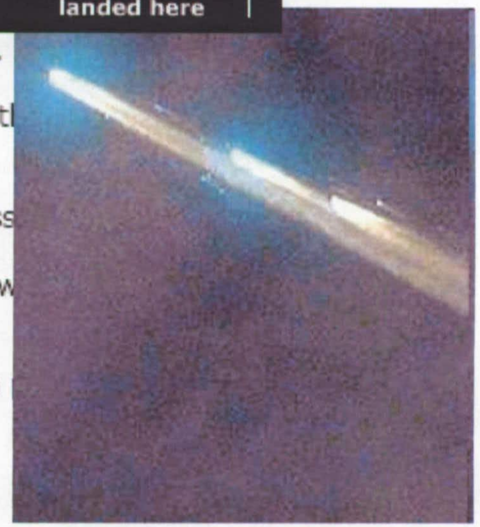


On current indications fro
Station is predicted to spa
New Zealand and Chile, a

Any variation to that date
atmospheric conditions.

Mir's current altitude is a
2.4km per day. While this … nd to increase as Mir gets lower.

Mir will be brought back i … ontrolled braking impulses after t
reaches an altitude of 220 … mpleted in about six hours.



NASA and ESA are following the flight of Mir and information gathered is being passed to Russian Miss

Two officers from the Australian Embassy in Moscow will be in the Space Centre during re-entry and w
real-time information to EMA on the progress of the operation.

EMA will continue to issue updates on the re-entry process and will advise arrangements being put in
briefings around 21-22 March.

Summary of Key Issues

- *Informed Consent*
  - Common measures of risk
  - Agreement on "Baseline" Risk
  - Consistent risk assessment methods
  - Protocols for aggregating risks
  - Protocols and institutions to receive risk information to represent their constituencies

Summary of Key Issues

- *Emergency Planning, Preparation, Communication & Response*
  - Launch area international exposure
    - Who:
      - Launching nation and host nation different
      - Shipping lanes
      - Airways
    - Affected parties need
      - Information on risk characteristics
      - Notification/Acceptance by populations exposed to risk above baseline
      - Pre-planned response given a disaster
      - Notification of a disaster

Summary of Key Issues

- *Emergency Planning, Preparation, Communication & Response*
  - Down range international exposure
    - Who:
      - Land: typically, all foreign
      - Shipping lanes
      - Airways
    - Affected parties need
      - Mobile
        - » Surveillance and vector to safety
      - Land
        - » Response advise and assistance
      - Notification/Acceptance by countries exposed to risk above baseline

Future Concerns

- It is foreseeable at some time a space booster will fail late in flight. The consequences may be debris impacting on foreign soil, possible impacts to sea lanes, and possible impacts to air corridors.
- The impact of that accident on future space flight and international relationships will be affected by how well we lay the ground work to
  - Involve parties at risk in understanding and accepting the elevated risks, recognizing that there are precedents with aircraft over flight and other technologies and
  - Implement emergency response procedures to manage the consequence of the accident.

Outline

- Have we achieved the goal already?
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- **Recommendations to the Space Faring Community**

Risk Communication

- FAA Standards
- RCC 321 Guidance
- ESA guidance?
- Other contributors?

Risk Analysis Standards

Annual Risk Measures

- Pr {Casualty producing accident)
- Pr (Accident with > $X/National Asset)
- Annual Collective (Societal Risk)
- Other?

Risk Reporting Protocol

National Representative

Informed Consent

- Treaty / protocol for acceptance
- Acknowledgement and Acceptance of Excessive risk
- Negotiating mitigation with launching states

Emergency Management

Standard Emergency Planning Scenarios

- **Requirements**
  Emergency Responders
- **Content**
  Launch Safety

Communications Protocols

- **Ships and Aircraft**
  Surveillance
  Spaceflight Management Program
  Vector to Safety
- **Land based populations**
  Involve Emergency First Responders
  Reverse 911

Emergency Response Plans

- **Warning**
- **Consequence Limitation**
- **Relief**

Lessons Learned