EFFECT OF WEATHER AND TERRAIN ON AIRLIFT OPERATIONS

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AIRLIFT AND ELEMENTS OF NATURE

Airlift is fundamental to military operations. Among others factors, the basic requirements for a successful airlift are a versatile delivery platform, favourable weather and hospitable terrain. Choice of an air superiority platform is limited by the inventory of an air force. Thus, given a platform, weather and terrain play a purposeful role in precise deliveries. Each of these elements can influence aerial delivery to the extent of absolute success or ultimate disaster. Visibility, cloud cover and precipitation are the main hazards for air transport operations[1]. Winds and illumination are also critical for airlift. The effect of terrain is limited and more predictable. Together, these elements have an even more profound effect. While weather is a dynamic factor, terrain is less so. Most of today's technology aims at diminishing the effects of weather and terrain. Efforts, though clandestine, have also gone into experiments to control weather.

History is replete with examples of the far-reaching effects of these elements on airlift operations. In the past, when flying was dependent on visual clues and accident investigation was less developed, accidents were generally attributed to pilot error. Years of flying experience later, weather still baffles pilots, paratroopers and meteorologists. Weather undergoes

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1. Ajey Lele, *Weather and Warfare* (New Delhi: Lancer Publishers & Distributors, 2006), p. 4.

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continuous change. Weather phenomena have scientific bases and follow the known laws of physics and chemistry. Knowledge about the weather at the mounting base, en route, and at the point of delivery is essential for planning airlift. It is equally important to know the likely changes in weather conditions that may affect the operations. Thus, weather forecasting assumes significance. Weather forecasting includes predictions of changes on the earth's surface caused by atmospheric conditions e.g. snow and ice cover, and tides. Forecasting entails collection and analysis of data through a variety of statistical and empirical techniques. But, due to a large number of variables involved, prediction becomes difficult. An element of subjectivity remains embedded in weather forecasting.

In the early years of aviation, all accidents while negotiating convective clouds were attributed to a single factor i.e. thunderstorm. The Thunderstorm Project (1946-47) established a variety of hazards within a thunderstorm[2]. The effect of weather is now well recognised due to refined accident investigation methods. Improved observational systems have led to the discovery and understanding of a variety of weather hazards. Study of accidents by Fujita led to the discovery of *micro burst*[3]. Weather and aviation related research led to the discovery of jet streams, mountain waves, Clear Air Turbulence (CAT), etc.

Ground-based, airborne and seaborne military and civilian observation platforms collect data continuously for analysis and for forecasting weather. Over the years, the ability to collect wide-ranging data has improved. As a result, forecasts are more accurate and reliable nowadays. Analysis of data enables identification of periods of calm or good weather in stretches of difficult weather conditions. Realistic plans, which take into account favourable situations, guarantee higher rates of success.

2. Project Thunderstorm (1947) was undertaken by the US Weather Bureau, the US Air Force and the US Navy to study the phenomenon of thunderstorms and to make flying safer. An audio-visual resume of the project presented by AIRBOYD.TV is available at http:// www .youtube .com/ watch? v= zv Yr2F iP3 jE, accessed July 11, 2011.
3. Online Encyclopaedia Britannica, available at http:// www .britannica .com/ bps/ search ?query= microburst, accessed on July 11, 2011.

Terrain relates to a piece of ground, especially with reference to its physical character or military potential. It also refers to the lie of the land and the vertical and horizontal dimensions of the surface. Terrain features can affect weather and climate patterns. This explains the rain in the coastal areas, the low clouds and rain in the eastern states of India and the dust storms in the Rajasthan desert. Terrain helps in determining weather patterns. Thus, separated by a few kilometres, the windward and the leeward sides of a mountain have different weather patterns; at times, they may differ phenomenally in their levels of precipitation or timing. Like weather, terrain constrains airlift and their effects are often overlapping. A major decision like delivery by means of a para-drop or a free-drop is often dictated by terrain.

IMPORTANCE OF WEATHER AND TERRAIN

There is a popular belief that today's aircraft with state-of-the-art avionics and ground assistance can fly in any weather condition and can evade all types of terrain. The fact is that in spite of the most sophisticated on-board and ground-based navigation and landing aids available to the modern aircraft, the basic requirement of terrain and meteorological information and weather forecast for airlift has not changed. If at all, the importance has only increased. Airlift missions still depend on accurate weather observation and reliable forecast. Under visual flight conditions, an observation or forecast error of a few hundred metres may not alter a decision to land. But under instrument flight conditions, at airfields equipped with the instrument landing system, if an aircraft is permitted to land in low visibility, an error of observation of a few metres can prove critical. An aircraft that takes off from Chandigarh (1,012 ft Above Mean Sea Level - AMSL) has to be sure of the temperature at Leh (10,682 ft AMSL) to determine the permissible all up weight and, hence, the capacity to carry passengers and supplies to Leh. Thus, judiciously planned early morning sorties enable airlift of maximum payload. According to the United States Department of Transportation (DOT) statistics, weather accounts for more than 40 percent of all flight delays, costing the passengers $6.7 billion.[4]

During Operation Imminent Thunder (Gulf War 1991), amphibious landings were planned on the Saudi coast to put psychological pressure on Iraq. But the hovercraft could not land due to strong surface winds. The mission had to be aborted after two attempts. Strong winds at that time of the year were ignored in that region. As per post war analysis of Operations Desert Storm and Desert Shield, weather conditions had played a major role during these operations. Some analysts are of the opinion that the coalition forces had faced a steep learning curve in coming to grips with weather predictions throughout the operations.[5]

For tactical reasons, low flying is a considered option. Nap of the earth flying is integral to most special operations. Operation Neptune Spear, that led to the killing of Osama Bin Laden, owes its success, among other reasons, to accurate knowledge of terrain that enabled US helicopters to enter Pakistani air space, making use of blind spots in the radar coverage due to the hills. Sound knowledge of the mountainous terrain and nap of the earth flying technique further facilitated their undetected flight to the objective[6]. Precise information about terrain is critical to avoid collision. Terrain (altitude) directly affects the payload too. It affects the range and performance of radars and terrestrial radio navigation systems. In hilly terrain, station keeping becomes difficult during formation flying. Landing runs increase and, therefore, aircraft require longer runways in high altitudes; payload also reduces. The Rate of Descent (ROD) of parachutes increases on a high altitude Drop Zone (DZ) resulting in a greater impact on landing and a higher rate of injuries. Hilly or mountainous terrain strongly impacts the construction of airfields and the orientation of their runways. Certain

4. Jim Glab, *Weather and Flight Cancellations: A Behind-the-Scenes at What Happens When Weather Causes Flight Cancellations*, March/April 2011, available at http: //www .executivetravelmagazine .com/ articles/ print/ weather- and- flight- cancellations, accessed on July 08,2011
5. Bales Fred, "Winter Weather in the Desert: Another Obstacle," *The Philadelphia Enquirer*, January 23, 1991.
6. Press Release Number: PR.152/ 2011, dated May 03, 2011, *Death of Osama bin Ladin: Respect for Pakistan's Established Policy Parameters on Counter Terrorism*, Ministry of Foreign Affairs, Pakistan, available at http: //www.mofa.gov.pk/Press_Releases/2011/ May/PR_152.htm., accessed July 18, 2011

DZs/ LZs (Landing Zones) cannot be used during the monsoons and when there is snowfall. Terrain appreciation is important for airlift operations.

Research and Development (R&D) agencies work relentlessly to resolve the problems resulting from adverse climate, weather and terrain. Detailed and accurate terrain intelligence is necessary to determine the requirements for new means of transportation, types of shelter and construction, weapons, and clothing. It is a basic requirement in developing new equipment and in the maintenance and modification of existing equipment. Knowledge of terrain and weather helps in avoiding human error accidents like Controlled Flight into Terrain (CFIT).

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WEATHER AND AIRLIFT

Weather is the state of the atmosphere at a given time and place, with respect to variables such as temperature, moisture, wind velocity and barometric pressure, etc. Weather phenomenon affecting airlift can be grouped as follows:

- Moving air e.g. surface winds, wind shear, jet streams and turbulence.
- Water in different forms (hydrometeorology) e.g. rain and snow.
- Visibility e.g. fog, mist, haze, smog, dust storm, volcanic ash, dust haze and smoke haze.
- Electrical phenomena e.g. lightning.
- Aircraft icing.

Cloud and sky cover, humidity, precipitation, surface wind, refractive index, wind-chill factor, illumination and visibility influence airlift in many ways. Critical weather phenomena like thunderstorms, turbulence, gusts, wind shear, heavy snowfall, or low visibility induced by fog, mist or haze reduce safety margins and sometimes result in incidents and accidents. Impact of weather differs for various phases of flight. Wind shear, fog, heavy snowfall and low visibility affect landing and take-off. Clear air turbulence is a characteristic en route hazard. Smaller aircraft with fewer aids are affected more than the larger aircraft. Para-drops are affected profoundly by weather conditions.

Aircraft, weapons and equipment of today – radios, radars, lasers, infrared radiation seekers, missiles and jammers – are extremely sensitive to atmospheric parameters. Weather affects even the equipment on the ground, thereby limiting operations. In May 2011, two Mi-17 helicopters deployed to ferry the Raksha Mantri, Mr A.K. Antony and his entourage on tour of the forward areas in Rajasthan could not get airborne because of excessive heat, leading to technical snags. The failure to start up the aircraft was attributed to batteries not giving optimal power in hot weather conditions.[7]

Accurate and timely weather information is an essential factor in conducting all phases of airlift operations. The climatology of an area of interest is an important consideration during the planning stage. Measurements of temperature, precipitation, ceiling and visibility affect equipment and supply drops. During planning and execution of airlift missions, the integration of accurate and timely weather intelligence is important. It provides planners and operators the freedom to make midway corrections in the plans, adjust mission flow, loads, and timing to ensure effective, efficient, and safe mission accomplishment. Additionally, space and atmospheric weather conditions have a significant impact on communications for airlift command and control. Also, a side that can alter weather and terrain to suit its interests has an advantage over its adversary that cannot do so.

TERRAIN AND AIRLIFT

Terrain affects all stages of an airlift. The effects are more pronounced at the time of take-off and landing of the aircraft than during normal flight. Manoeuvrability becomes restricted while flying in mountainous/ hilly terrain. It is a major consideration in selection of a DZ and methods of

7. "Red Faces in IAF Over Copter Snag: Problems in Choppers Force Antony, Army Chief To Travel by Road," *The Times of India*, May 05, 2011, p. 9.

delivery by air. Hilly terrain with thick foliage provides a restricted area for supply drops in the eastern sector. The DZs are small, with practically no margin of error on any side. Terrain accentuates weather. Wind Induced Drifts (WIDs) over small restricted DZs can land parachutes in deep ravines, making them irrecoverable. Thus, free-drop rather than para-drop is preferred over certain DZs. Similarly, free-drop is a preferred option while dropping relief material from helicopters for people marooned on small islands and rooftops during floods.

Analysts predict the absence of full-scale wars in the near future. In the days to come, conflicts are likely to involve small, mobile combat units equipped with aircraft, which can land and take off from unprepared or sketchily prepared surfaces. Therefore, intelligence on the terrain and its properties, to be used as an operating environment, will be important. Terrain intelligence is the information on the military significance of natural and man-made characteristics of an area. It is the study of the physical features on the ground for military operations. The quantitative and qualitative need of terrain intelligence is as essential as the need to know weather. Terrains that are generally found in the Indian subcontinent are discussed in the succeeding paragraphs with their relevance to airlift operations.

Desert: A desert is an arid area with little or no rainfall. It could be mountainous, rocky or sandy with extremes of temperatures. Air-drop may be possible and advantageous on the soft sandy surface. But helicopter operations may be difficult to manage due to the high temperatures and the dust raised by the downwash (brown ring effect and brownout). Visual navigation may be difficult in the absence of landmarks on the ground.

Hilly and Mountainous: Mountains are landforms that stretch above the surrounding area, usually in the form of peaks. Aircraft manoeuvrability is restricted in hilly terrain. Because of the elevations, such terrain is colder than the plains and at, times, wetter than expected. Strong winds and fog are encountered regularly. Take-off and landing runs increase with altitude and the payload reduces, thereby, lowering the overall capacity and performance. It is difficult to find DZs of reasonable sizes for para-drops. Slight inaccuracies in drops over restricted DZs can land supplies in inaccessible areas. Rendezvous of troops dropped in the hills may take a long time. Mass para-drops are rarely possible due to the restricted nature of the terrain. Besides, the rarefied atmosphere of the high altitudes results in increased rate of descent of parachutes, leading to injuries to paratroopers and damage to equipment. Ground undulations also contribute to landing injuries to troops. Mountain weather necessitates acclimatisation, use of breathing oxygen and special clothing.

Jungle: A jungle is characterised as a rainy and humid area with impenetrable vegetation. It is generally found within the tropics, near the equator. The climate varies with location. Close to the equator, there are heavy rains all the year round. Farther from the equator (India and Southeast Asia), there are distinct wet (monsoon) and dry seasons. It is difficult to find clear areas to be used as DZs or LZs. They offer possibilities for Special Heliborne Operations (SHBO) rather than air-drops. Very little visual terrain association can be accomplished because of the foliage.

Snow: This type of terrain experiences extended periods of sub-zero temperatures and the ground is generally covered with ice or snow, particularly during the winter season. Such terrain may be suitable for airlift by helicopters with specially prepared landing areas. Air-drop of supplies and equipment may be possible on both ice surface and snow. Snow also offers a soft landing surface for para-drop of personnel.

Marshland: This is typical marshy and barren terrain. The ground surface remains inundated for a greater part of the year due to rain. During the remaining part of the year, scattered patches remain wet. Though some places look dry, they actually have slush underneath and the ground gives way. The Rann of Kutch is generally flooded from June to October by sea water, creating salt lakes. The ground remains inundated and there are salt deposits because of the sea water. When the monsoon abates, the waters recede, leaving behind a morass, which gradually dries up and turns into pastures. It is like a desert – flat, firm and quite bare except for a few islands with scanty plant growth. The surface is generally unsuitable for effective aerial delivery.

Urban Terrain: It includes man-made structures like buildings, roads, rails, bridges seaports and airports, etc. It represents the environment in the context of urban warfare. The increasing focus on terrorism and insurgency indicates that combat in built-up areas is unavoidable. Aerial delivery of troops during the terror attacks in Mumbai (26/ 11) was an operational necessity. Such situations are expected to arise more often in the future. Besides, humanitarian assistance often entails airlifts into urban terrain.

Islands and Coastal Terrain: Islands and coastal terrain pose a grave challenge due to their proximity to the sea. While landing operations are the same as on airfields elsewhere, air-drops are complex and weather over such terrain makes operations even more intricate. Errors in accuracy of drops can spell disaster. Use of life jackets and other floatation equipment is a necessity and is at the cost of arms, ammunition and other combat equipment. Jettisoning the parachute and avoiding entanglement with the canopy and the suspension lines in the water is a difficult exercise.

MITIGATION

It is possible to tone down the severity of some effects of weather to suit the requirements of the operations. The capability and capacity of aircraft, parachutes, and the men who operate them, matters in dealing with the effects of weather and terrain. Aircraft are fitted with equipment to achieve favourable conditions in a limited or confined space. These systems can be operated by the aircrew at will, or could be programmed to function automatically. Temperature, pressurisation and illumination control are means of overcoming weather. They help optimise conditions in the cockpit and in the cargo compartment. It is also possible to mitigate the effect of weather on the aircraft surfaces using chemicals and electromechanical devices. They suppress and/ or neutralise the effects of weather. Aircraft weather mitigation can be thought of as a continuous process, with the need to avoid all adverse weather at one extreme and the ability to safely operate in all weather conditions, at the other.

The size and capacity of an aircraft determines its ability to carry equipment to mitigate weather. Smaller aircraft tend to get thrown about in turbulent weather. An air-ambulance, Pilatus PC-12, crashed in Delhi amid bad weather and high-velocity winds on the night of May 25, 2011. Shortly before the crash, the pilot had communicated to the air traffic control that he was facing bad weather. The aircraft then vanished from the radar. According to some sources, when the aircraft was cleared by the Air Traffic Control (ATC) to descend, it appeared to climb further before descending at a very steep rate and crashing. There was no cockpit voice recorder or flight data recorder on board since such small aircraft usually are not equipped with heavy devices[8].

Technology and innovation has led to improvements and enhanced flight safety. This has also led to greater operational capabilities of aircraft in varied weather conditions. Improvement in aircraft and parachute performance and ability to safely operate in adverse weather further enhances airlift capability. The following developments illustrate the trends:

- Thrust reversers improve braking.
- Anti-lock braking systems avoid skidding.
- Grooved runways improve traction in rainy weather.
- Heated leading edges reduce ice accumulation.
- De-icing fluids clear airframes of ice accumulation.
- Lightning detection systems indicates lightning discharges.
- Crosswind landing gear improves crosswind-landing limits.
- Gyroscopic instruments enable flying in reduced visibility conditions.
- Electrical shielding prevents damage to aircraft from lightning strikes.
- Autopilots and auto-throttles help maintain established flight paths.
- Gust alleviation systems reduce the ill effects of turbulence.
- Flight Management Systems (FMS) control piloted/autopilot-assisted flight.
- Auto-land systems enable a hands-off approach and landing.
- Enhanced turbulence mode radar identifies turbulence.
- Ram air parachutes with good glide ratios can counter strong winds.
- Improved lighting (aircraft/airfield) enables operations at night and in poor visibility conditions.

8. *The Asian Age*, May 27, 2011, available at //www .asianage .com/ india/ dgca-points- high-velocity- winds- weather- plane- crash- 051, accessed July 13, 2011.

- The Instrument Landing System (ILS) provides precision approach guidance for landing.
- Remotely controlled steerable parachutes ensure precise deliveries.

In desperate times, the effect of adverse terrain has been mitigated in innovative ways. The 1980 Iran hostage crisis was a crucial time for the US. Operation Eagle Claw had failed in the Iranian desert. A second rescue was attempted that aimed at landing a Hercules aircraft in a sports stadium close to the US Embassy in Tehran. To overcome the difficulty of landing a massive aircraft in restricted space in urban terrain, radical modifications were initiated on the aircraft – rockets were fitted at different points on the fuselage of the aircraft to enable vertical take-off and landing. Trials were fairly successful. Incidentally, the hostages were released before the aircraft could be put into operational use[9]. This is a passive way of mitigating the effect of terrain.

A step ahead is active terrain mitigation. It involves physical modification of terrain to support requirements. The US Navy's Construction Battalions (CBs), better known as SeaBees have a history of building bases, bulldozing and paving thousands of miles of roadway and airstrips, and accomplishing a myriad other construction projects in a wide variety of military theatres. They constructed six 8,500+ ft runways at the rate of one runway per 53 days; over 18 km of taxiways; hard-standing to accommodate over 400 bombers, and accommodation for 50,000 personnel and office complexes, on the islands of Tinian and Saipan in a record time of less than a year during World War II. Tinian became the largest and busiest airport in the world in midsummer 1945. Nearly 19,000 combat missions were launched from these islands, including the sorties that dropped the atomic bombs on Nagasaki and Hiroshima[10].

About 2,600 SeaBees are currently deployed in about 20 different countries around the globe, supporting a variety of humanitarian missions

9. "Crash Landing", *Popular Science,* vol. 251, July 1997 (Canada: Bonnier Corporation, 1997), p. 32.
10. "The Use of Tinian Island During World War II," available at http:// web .mst .edu/ ~rogersda/ umrcourses/ ge342/ Tinian %20Island .pdf, accessed July 23, 2011.

China is among the few countries that invest in weather modification.

and contingency operations. SeaBees were among the first forces in Afghanistan after the 9/11 attacks, to upgrade and repair airfields. Portions of two battalions have been deployed there since January 2009.[11]

CONTROL OF ELEMENTS OF NATURE

In the early years of aviation, it was considered prudent to avoid weather and terrain. Then, technology made it possible to mitigate the undesirable effects of these elements of nature. The next logical step in this direction is to control them, because such ability can enable smooth airlift operations. Control of weather implies modification of atmosphere to achieve desired effects. Control over a limited area, mainly to cause rain, has been done in many countries. Control over a larger area and for more time has relevance to agriculture. As atmosphere is a continuous entity without borders, any effort to change it can affect regions beyond the geographical limits of a country. Therefore, environmental issues like control of weather, climate change and global warming, etc. acquire a geo-political hue. Militaries and governments of neighbouring countries, environmentalists, social activists, naysayers and the media even within the country oppose the efforts. The debate between security and development, on one side, and the conservation of environment, on the other, goes on.

China is among the few countries that invest in weather modification. During the 2008 Olympics in Beijing, the Chinese Meteorological Department had forecast rain over the main stadium hosting the Opening Ceremony. The humidity in the vicinity of the stadium touched 90 percent. It is believed that the Chinese Weather Modification Office made a deliberate attempt to prevent the rain clouds from drifting in and causing rain over

11. "Additional Seabee Battalions Deploying to Afghanistan" Story Number: NNS091222-01; Release Date: 12/22/2009 7:58:00 AM on Navy.mil the official website of the US Navy, available at http://www.navy.mil/search/display.asp?story_id=50316, accessed on August 04, 2011.

the stadium. They fired rain dispersal rockets from different sites.[12] It was probably because of those rockets that the clouds dissipated on the site, causing more than 100 mm rain, leaving the stadium dry. This type of wilful manipulation of weather has localised effect. Cloud-seeding, as it is called, is a relatively well-known practice that involves shooting various chemicals into the clouds, such as silver iodide, salts and dry ice, that bring about the formation of larger raindrops, triggering a downpour. Chinese scientists seem to have perfected another technique that reduces the size of the raindrops, delaying the rain until the clouds move on.[13]

In the late Sixties, the US prolonged the monsoon in Vietnam (Project Popeye). Artificially produced excessive rain resulted in flash floods and blocked the enemy vehicles along the Ho Chi Minh Trail, which were then attacked by the US aircraft.[14] According to some estimates, the US forces reaped rich dividends by controlling the weather. There are some who believe that in one respect, the Americans also paid a price for the manipulation of weather. In November 1970, the Son Tay Raid (Operation Ivory Coast) for the rescue of 61 American Prisoners of War (POWs) failed because the prisoners had been transported to another location, Dong Hoi, due to the problem of flooding caused by Operation Popeye.[15]

Another much talked about, but less known American project for weather control is the High-frequency Active Auroral Research Project (HAARP). It is a ground-based weapon being developed in Alaska. The device focusses radio-frequency energy (a beam of more than 1.7 gigawatts) into the atmosphere, which ricochets when it encounters the ionosphere. The radiations bounce back onto the earth in the form of long waves, which penetrate living organisms, the ground and the oceans. It is said that it can

12. Ajey Lele, "China's Experiments with Weather Modification: A Cause for Concern" available at http://www.idsa.in/idsastrategiccomments/ChinasExperimentswithWeatherModification_ALele_121009, accessed July 21, 2011.
13. Barbara Demick, "China Plans to Halt Rain for Beijing Olympics", *Los Angeles Times*, January 31, 2008 available at http ://travel .latimes .com/ articles/ la-trw- rain31 jan31, accessed July 12, 2011.
14. Lele, n. 12.
15. Al Hemingway, "Daring POW Raid at Son Tay", *VFW Magazine*, November 1995, available at http: //www .pjsinnam .com/ vn_ history/ stories/ Son_ Tay .htm, accessed on August 16, 2011.

influence the environment in several ways. It can control the physical and mental processes of human beings; jam global communications systems; change weather patterns over large areas; interfere with wildlife migration patterns; and, unnaturally impact the earth's atmosphere.[16] Some people believe that the uncommon natural phenomena like the Indonesian tsunami (December 2004), floods in Pakistan (July 2010), the cloudburst in the Leh-Ladakh region (August 2010)[17] and the tsunami and earthquake in Japan (March 2011) could have been the result of similar experiments conducted to control weather.

According to Dr. Nick Begich and Jeane Manning, in 1958, Dr. Edward Teller, the father of the H-bomb proposed to blast a portion of coastline off the map of Alaska. It was viewed as an effort to prove that nuclear explosions could be used for geographical engineering. Project Chariot, a part of Project Plowshare at Lawrence Radiation Laboratory, aimed at exploding six thermonuclear bombs underground at Cape Thompson, Alaska, to dig a harbour.[18] Teller was quoted as telling the Alaskans, "If your mountain isn't in the right place, drop us a card."

The veracity of such stories and media reports is doubtful and cannot be verified because such efforts are shrouded in secrecy.

A PEEP INTO THE PAST

Weather and terrain have a greater impact on battles than any other physical factor, including weapons.

— G.R. Svoboda[19]

Outcomes of many a war in history have been attributed to the effects of weather and terrain. Forces have accrued advantage by paying heed and

16. Jeane Manning and Dr Nick Begich, "Angels Don't Play This HAARP: Advances in Tesla Technology," extract available at http: //www .biblioteca- tercer- milenio .com/ mispdfs/ HAARP.pdf, accessed July 05, 2011.
17. "Climate Himalaya," available at http:// chimalaya .org/ 2010/ 08/16/the-devastating-flood-from-cloudburst- in- leh- ladakh- a- chinese- experiment- of- weather- bomb- or- an-effect- of-the-undergroud- ufo- bases- in- the-h imalayas/, accessed on August 17, 2011.
18. Manning and Begich, n. 16.
19. G.R. Svoboda, *Military Weather History,* Army Weather Support (A. Deepak Publishing, 1986), available at http ://space .au .af .mil/aberdeen/history.htm, accessed July 11. 2011.

suffered heavily by disregarding weather and terrain. Contempt of these elements of nature has resulted in misery and has led to many mission failures. Yet, weather does not form a Principle of War. Weather and terrain may appear to be irritants that hinder smooth conduct of operations but they cannot be treated with disdain. Each situation in the past and each new set of circumstances of the future is unique and different. Lessons learnt and the conclusions drawn from a situation cannot be applied as templates but situational similarities may demand typical responses. The basic characteristics of weather and terrain do not change. Therefore, responses based on past experiences can make a favourable difference in the outcome in repetitive situations. The cognitive approach can save resources, effort and precious time.

It may be argued that the Iran hostage rescue is not relevant in the Indian subcontinent or what happened in World War II is not relevant now. A hostage rescue attempt like Operation Eagle Claw (Iran) may not be relevant in its entirety but blinding due to dust (brownout) is a problem of helicopter operations in the deserts and is as relevant in the Thar Desert as it was in Iran. More similarities can be drawn, and learning value can be attached. Some instances of airlift from the past are illustrated here to bring out the marked influence of weather and terrain on airlift operations.

Normandy Landings (D-Day)

The battle of Normandy launched the invasion of German-occupied Western Europe during World War II by the Allied forces. It commenced on June 6, 1944, with the Normandy landings (Operation Neptune, commonly known as D-Day). An airborne assault (nearly12,000 troops) preceded an amphibious assault (almost 7,000 vessels). Nearly 160,000 troops crossed the English Channel on June 6, 1944. More than three million troops were in France by the end of August 1944.

It was a massive joint Services operation, with naval, aerial and paratroop elements supporting the main amphibious assault. They required specific meteorological conditions: a late-rising full moon, a receding tide, good visibility, sparse cloud cover and low winds. The unreliable Channel weather made this an elusive combination. After a postponement, the operation was scheduled for June 6, 1944; even then, conditions were less than ideal, with blustery seas and 50 per cent cloud cover.[20]

Initially, meteorologists had predicted inclement weather – rain and winds, unsuitable for a para-drop. The timing of the invasion by the Allied forces was finally dictated by a favourable weather forecast. The window of opportunity for launching an invasion was limited to only a few days in each month as a full moon and a spring tide was a must. On June 4, conditions were clearly unsuitable; high winds and heavy seas made it impossible to launch landing craft, and low clouds made flying difficult. However, based on the weather reports transmitted by the HMS *Grindall*, Eisenhower's chief meteorologist predicted a slight improvement in the weather for June 6. It was a precarious situation. After much discussion, Eisenhower decided to launch the invasion. The German weather analysts, on the other side, felt that the weather would prohibit successful crossing of the English Channel. This forecast contributed to the unsuspecting mood of the Germans on that day. They believed an invasion would not be possible for several days. As per some accounts, troops stood down and, many senior officers, including Rommel, were unavailable. They took the Allied operation lightly, thereby, fatally compromising their ability to repel the landings.

The Allied forces were rewarded for their perfect analysis and for availing the opportunity that came their way; and the Germans paid for their disdain for weather.

Operation Husky (1943)

Operation Husky, was a World War II campaign, in which the Allies took Sicily from the Axis Powers. It was an amphibious and airborne operation, followed by six weeks of land combat. It marked the beginning of the Italian Campaign. Eisenhower's planners considered three important factors: the island's terrain, the location of the major airfields, and the location of the enemy forces.[21] But they disregarded weather.

20. Phil Edwards, "D-Day: The Normandy Landings," BBC History available at http:// www .bbc .co .uk/ history/ worldwars/ wwtwo/ ff7_ dday .shtml, accessed July 14, 2011.
21. E. M. Flanagan Jr., *Airborne - A Combat History of American Airborne Forces* (New York: Ballantine Books, 2002), p. 75.

A combined US-British team at Algiers developed the airborne phase of the operation. It was launched from bases in North Africa. Strong winds of up to 45 miles per hour blew the troop-carrying aircraft off course and the US force was scattered widely over southeast Sicily. The result was that around half the US troops failed to rendezvous. One-eighth of the Combat Team was dropped as planned and the remaining was scattered some 60 miles on the island[22]. Only 12 out of 147 British gliders landed on target, and 69 crashed at sea.[23] A reinforcement drop resulted in friendly-fire casualties. Despite forewarnings, Allied anti-aircraft guns, both ashore and aboard US Navy ships, shot down 23 of the transport aircraft as they flew over the beachhead.

The Allied forces suffered heavy losses for ignoring weather. Their commanders were forced to reassess the use of airborne forces after the many inaccurate drops and the friendly fire incidents. Improved training and some tactical changes kept the airborne units in the war[24].

Berlin Airlift: Black Friday (August 13, 1948)

Post-war Germany was divided into three sections: the United States, Great Britain and France controlled the Allied part. The Soviet Union dominated the other part. The city of Berlin, although located in the Soviet half, was similarly divided – West Berlin, occupied by the Allies and East, by the Soviets. In June 1948, the Soviet Union attempted to control all of Berlin by cutting off surface traffic to and from the city of West Berlin. They wanted to starve out the population and cut off their business, to gain control. The Allies responded with daily airlift of much needed food and supplies into West Berlin.[25]

22. Ibid., p. 81.
23. "Allied Invasion of Sicily," available at http:// en .wikipedia .org/ wiki/ Allied _invasion _of _Sicily, accessed on July 11, 2011.
24. "Airborne Forces" available at http:// en .wikipedia .org/ wiki/ Airborne_ forces, accessed July 14, 2011
25. Introduction to The Berlin Airlift, available on the official website of Harry S. Truman Library, available at http:// www .trumanlibrary.org/whistlestop/study_collections/berlin_airlift/ large/accessed July 14, 2011.

Commencing on June 24, 1948, the Berlin Airlift reached a plateau in July 1948. Gen William H. Tunner of the Over the Hump (India-Burma-China) airlift fame, introduced small changes and streamlined the procedures thereby reducing the turnaround time and enhancing the daily tonnage. The Berlin airbridge had a peculiarity – there were many bases to feed aircraft into Berlin, but only two airfields were available to accept the aircraft that had to fly in restricted air corridors over or near the Soviet airfields. If the aircraft could not land due to any reason, they had only a 20-mile radius to orbit in.

On August 13, 1948, the visibility suddenly dropped again due to low clouds that hung at the level of apartment buildings surrounding the Tempelhof airfield. A sudden cloudburst obscured the runway from the tower and the radar could not penetrate the rain. The radar controllers and the ground control approach controllers lost control over the situation. One C-54 overshot the runway, crashed into a ditch and burst into flames; the crew got out alive. Another C-54, coming in with a maximum load of coal, touched too far down the runway. Harsh braking to avoid the burning C-54, led to tyre bursts. Another aircraft realised too late that it was heading for an auxiliary runway, still under construction. It slithered, slipped and ground looped. The Air Traffic Control (ATC) began stacking the aircraft that were coming in at a three-minute interval. Soon the stack was packed from 3,000 to 12,000 ft in the air space over the runway[26].

Poor visibility, several aircraft stacked overhead, more joining in at regular intervals, confusion on the ground, and in the air – the conditions were ripe for more mishaps. Gen Turner, whose aircraft was also airborne at that time, took immediate action to prevent more accidents. Through the ATC, he ordered all other aircraft in the stack to return to their bases. A much bigger disaster was thus averted.

Weather was the cause of a near complete disaster on Black Friday. Among the steps taken to make airlift safe, was the decision to allow all airlift aircraft a single pass at landing. If for any reason the pilot was unable to land in the first approach, he was ordered to return to his home base in

26. D. M. Giangreco and Robert E. Griffin, *Airbridge to Berlin –The Berlin Crisis of 1948, its Origin and Aftermath* (California: Presidio, 1988). p. 122.

West Germany. This prevented stacking. Another rule introduced by Tunner was to adhere to instrument flight rules under all weather conditions. In the constantly changing weather conditions in Berlin, this led to standard operating procedures.

Adverse weather in urban terrain can bring airlift operations to a standstill even in peace-time. Preparedness through realistic training and innovative thinking can help overcome obstacles.

Operation Cactus: The Maldives, November 1988, Revisited

In a daring airborne operation, the Indian armed forces rescued President Maumoon Abdul Gayoom of the Maldives on November 03, 1988. Two IL-76 aircraft airlifted troops from Agra to Hulule airport. The President was rescued with relative ease. Seemingly, it was a copybook operation, conducted flawlessly. A closer scrutiny revealed areas that would deserve a relook if a similar operation were to be undertaken in the future. One such aspect was the decision whether to para-drop or to land the troops on the island. The final decision was influenced largely by the limitations posed by the factors of weather and terrain.

Among the uncertainties at the time of the launch of the operation was that of control over the runway at Hulule. One was not sure whether the friendly forces or the terrorists were in control of the airfield. The nationalities and the levels of training of the mercenaries were unclear. Therefore, plans could not be based on the enemy's known capabilities and style of operation. Experienced mercenaries would strive to wrest control of the airfield at the earliest. It was a matter of chance though that the terrorists had ignored the island of Hulule with the main runway. It was a fluid situation when the ILs took off from Agra. A flying time of four long hours from Agra to Hulule could alter that state and enable the terrorists to block the runway and render it insecure for landing. They could take positions around the runway and fire at the landing aircraft. Availability of shoulder-fired missiles with the terrorists would raise the risk. In that eventuality, landing an aircraft would endanger the complete force. Returning to Sulur, or to Chennai, the nearest Indian air bases, with the full aircraft load could have been a Hobson's choice.

A para-drop rather than a landing would have addressed this issue summarily.

A few facts about Maldives and some calculations will establish the impracticability of a para-drop. Each aircraft had nearly 120 troops. Initially, it was contemplated that 60 from each aircraft would be para-dropped if the runway was unsafe for landing. In November 1988, the runway at Hulule measured about 7,600 ft, with water all around. So close was the sea that, in most places, one could throw a stone from the runway shoulder into the water. The distance from the edge of the runway to the seashore varied (generally about 300-400 ft). The length was much in excess of that required to drop 60 para-troopers (see Table 1 for details).

Table 1: Simple Calculation* of DZ Length (for IL-76) for Para-drop

DZ Length for Para-drop (in feet) = $S_* R_{1*} N$, where S = Aircraft Speed in feet per second (fps), R = Jump Rate and, N = Number of Jumpers	
Aircraft Drop Speed, S	= 260 ± 10% kmph ≈ 250 kmph (say) ≈ 227.8 feet per second
Jump Rate (Side Door Exit), R	= 0.8 seconds/ jumper (for calculation)
Jump Rate (Aft End Exit), R_1	= 0.7 seconds/ jumper
Number of jumpers exiting simultaneously from each door for minimum spread on the ground (max 126)	= 30 from each Side Door + two sticks of 33 each from the Aft End
Ideal number of jumpers exiting simultaneously from each door for minimum spread on the ground (for 60), N	= 14 from each Side Door + two sticks of 16 each from the Aft End
Minimum DZ Length for 60 jumpers (without catering for overshoot or undershoot for error), in feet	= $S_* R_* N$ = 227.8 $_*$ 0.8 $_*$ 14 ≈ 2552 feet
* For simplicity of calculations, allowance for undershoot/ overshoot error is being disregarded.	

In absolute no wind condition, if the troops exit over the runway (allowing for the forward throw on exit), they land on the runway. Since, the Maldives are located north of the equator, easterly winds (about 20 kmph) were expected. Actual weather was not known. In any case, Wind Induced Drift (WID) on the parachutes had to be offset to prevent the troops drifting into the sea. WID can be approximated on the basis of actual or forecast winds (see Table 2).

Table 2: Simple Calculation of Wind Induced Drift (WID) on Parachutes

Drift of a Parachute (in metres), $D = K_* A_* V$, where K = Constant, depends on the type of parachute (3.0 for personnel parachutes), A = Drop Altitude, expressed in 100s of feet Above Ground Level (AGL) and V = Mean effective wind or velocity of wind in knots
Assigning Values to variables: K = 3.0, A = 15, V[*] = 10.8
Thus, WID would have been = $3.0 _* 15 _* 10.8$ = 486 metres $\approx$ 1,600 feet

As can be seen, with winds of a strength of 20 kmph, the drift experienced would have been about 1,600 ft. Exploring the formula further, it can also be concluded that for a variation of every kilometre in the Mean Effective Wind (MEW), there would have been a difference of 80 ft in the drift – a precarious situation. Fully equipped troops drifting into the sea would have been the nemesis of the operation. A streamer[27] or a drifter[28] could not have been dropped at night. Dropping smaller sticks of jumpers to attain progressive accuracy would have increased the number of passes, and thereby the flying activity over the runway, eliminating the surprise and alerting the terrorists. The darkness of the night and absence of any ground references would also have compromised accuracy.

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*. In this case, Mean Effective Wind (MEW), which accounts for the speed and direction of winds at different heights through which the parachute descends, cannot be calculated since actual winds at Hulule were not known at the time of the operation, 20 kmph ($\approx$ 10.8 knots) was generally experienced at that time of the day and year as per data available from different sources.

27. A streamer could be a long piece of paper or cloth with the descent characteristics of a parachute. It is dropped to assess the WID.

28. A drifter is person para-dropped singly for assessment of WID.

Therefore, the idea of a para-drop on the runway was seriously contemplated and sensibly rejected by the planners – a repetition of the history of Operation Mercury (1941) and Operation Husky (Sicily, 1943) was scrupulously avoided. Today's ram air parachutes can offset the effect of winds to a great degree and enable accurate drops in restricted areas. Use of ram air canopies with control and guidance can ensure reasonably accurate supply drops of small consignments also.

WEATHER AND TERRAIN: NOT ALWAYS IMPEDIMENTS

> *The rain fell alike upon the just and upon the unjust, and for nothing was there a why and a wherefore.*
>
> — W. Somerset Maugham,
> *Of Human Bondage*, 1915

Weather and terrain are unavoidable elements of nature – not necessarily adversaries of airlift operations. Like gravity, they are impartial to all. They favour no side. But their effects could be an advantage for a side or detrimental to its interests. What is a blessing for one side could be a curse for the other. The effects on airlift operations are conditional and situational. A thick layer of clouds and strong surface winds, which inhibit an air-drop, are sure to gratify a defending force. A given weather condition could be a boon or a bane for the same side, depending upon the need. Strong winds are hazardous for a mass drop with static-line deployed parachutes. But a special operation involving High Altitude High Opening (HAHO) insertion could benefit immensely from strong tail winds by way of additional stand-off distance. Similarly, a layer of low clouds can conceal a High Altitude Low Opening (HALO) team.

Mountainous terrain, which poses hurdles to airlift operations, was used cleverly during Operation Neptune Spear. The Pakistanis' audacity in Kargil may have been prompted partly by their perceived inadequacies in the logistics infrastructure on the Indian side (to move men and material to that region) and India's inability to respond decisively and speedily due to terrain.

Weather and terrain potentially benefit and hurt each warring side in different ways. Theoretically, they influence the freedom of operation to an

extent that they:
State I. Favour friendly forces and are detrimental to the enemy.
State II. Favour both, the friendly forces, and the enemy.
State III. Detrimental to both, the friendly forces and the enemy.
State IV. Detrimental to the friendly forces and favour the enemy forces.

Ideally, operations must be planned when the effects of weather and terrain favour the friendly forces and hinder the enemy operations (State I) and must not be planned when conditions favour the enemy and hinder the friendly forces (State IV). However, given a set of weather and terrain conditions, the state can be manipulated and the operational freedom can be enhanced considerably through:

- Good equipment for sensing, observation and data collection.
- Means for data processing, analysis and dissemination.
- Aircraft and delivery systems that can mitigate the adverse effects.
- Use of equipment to mitigate adverse effects.
- Reliable weather and terrain intelligence.
- Availability of real-time data and its analysis.
- Judicious/cunning exploitation of windows of opportunities.
- Awareness through education and training.
- Greater stress on technical knowledge of geology, forestry, climatology and meteorology, etc.
- Eternal preparedness.
- Use of aids to enhance performance.
- Control of weather and modification of terrain.
- Employment of tactics to circumvent adverse conditions.

Ability to airlift in adverse conditions can accrue gains against terrorists and insurgents. In areas with truly bad weather and difficult terrain, the adversary may be forced to remain confined to shelters. Accurate and reliable weather information and terrain intelligence, audacious planning and precise delivery of teams of special forces can lead to success.

DEALING WITH WEATHER AND TERRAIN

Risk = f (Weather, Terrain, Exposure, Vulnerability)

Risk to airlift operations is a function of weather and terrain, and the exposure and vulnerability of the airlift platform to these elements of nature. It follows that risk can be reduced by mitigating or controlling weather and terrain, reducing the exposure of the airlift forces to the elements of nature and by lowering vulnerability.

Delivery platforms (aircraft) and equipment are important considerations while evaluating risk through weather and terrain. Use of aircraft with Vertical Take-off Landing (VTOL) capability like the Bell Boeing V-22 Osprey can overcome problems of landing in restricted areas/short runways. The Boeing CH-47J Chinook is another versatile heavy lift helicopter that has proved itself in different terrains and weather in many wars, from Vietnam to Afghanistan. Its hovering capabilities enable deliveries in the most difficult terrain.

An earthquake in Sikkim (September 2011) posed the problem of the aid workers and the relief material reaching the quake hit areas due to landslides. Bagdogra, the runway nearest to the epicentre, did not have night landing facilities. But two C-130J Super Hercules aircraft could land there because they had night landing equipment and capability. Relief material and a team of 200 National Disaster Relief Force (NDRF) personnel could be landed at Bagdogra beyond daylight hours.[29] Ruggedness and operability in most types of terrain and weather conditions is an important criterion while selecting aircraft and other equipment for operational use.

Some of the limitations can be overcome with ingenuity and innovativeness.

Such crises cannot be ruled out in the future. Non-availability of a runway due to a natural cause or due to enemy action can jeopardise operations in a big way. In times of crises, if long stretches of wide roads are available, they can be used for landing personnel and supplies closest to the site of

29. Manu Pabby, "For first time, IAF Deploys its 'Special Operation' Aircraft," *Indian Express*, (New Delhi) September 19, 2011), p. 2.

action, in very exceptional cases.[30] A strategic approach to infrastructure development can address this issue. While at it, there is a need to ensure that the roads leading to the airfields are also kept clear of obstructions – mighty airlift aircraft will serve little purpose if the men and material to be airlifted cannot reach the airfields in time. Wide approach roads to airfields, clear of impediments will reduce response times during national emergencies.

Weather satellites give vital information on weather. Unarmed Aerial Vehicles (UAVs) can also be used for real-time weather and terrain related information in areas of interest to buttress airlift operations.

Some of the limitations can be overcome with ingenuity and innovativeness. Carrying less fuel and managing sorties in the early hours of the morning enables maximum airlift in high altitude areas.

In India, weather and terrain differ drastically, from Dras and Kargil (sub-zero temperatures and mountainous terrain) to Rajasthan (desert terrain with 45C) to the hot and humid northeast, to the Naxal infested jungles of Madhya Pradesh, Andhra Pradesh and Bihar. Airlift is affected by these natural conditions. Weather satellites give vital information on weather. Unarmed Aerial Vehicles (UAVs) can also be used for real-time weather and terrain related information in areas of interest to buttress airlift operations. Geospatial engineering is emerging as a new field for development dissemination and analysis of terrain related information that is accurately referenced. It is an aid to tactical planning.

The true capabilities of countries to modify or control weather are not in the public domain. Research and development is shrouded in mystery. Glimpses of the capabilities of the US and the China suggest, beyond reasonable doubt, that they are way ahead of the rest of the world. India could jump on the bandwagon for similar research to meet its needs. Learning from others' experiences would be valuable because their past could be any country's future. Collaboration for a humanitarian cause could be top on

30. The Pakistan Air Force has done trial landing of fighter aircraft on a road. Some of the Scandinavian countries have plans to resort to use of roads as runways during crises.

the agenda. An option could be to collaborate with other countries that have climate like ours and face weather constraints like we do. It is, however, less likely that the *haves* in these fields would encourage partnership beyond a limit. Therefore, as a last resort, we could carve a lonely path to suit our needs, possibly without affecting others adversely.

There is a need to look ahead and plan holistically. Learning from the experience of others may simplify the path ahead. An integrated plan for the Next Generation Air Transportation System (NGATS) was submitted to the US Congress in 2004. It is expected to enhance the level of operations considerably. A Joint Planning and Development Office (JPDO) coordinates and manages the efforts of various departments and experts from the public and private sectors to achieve NGATS. The JPDO organisation includes eight interagency Integrated Product Teams (IPT), one of which, the Weather IPT, addresses the impact of weather on the safety, efficiency, and capacity of the air transportation system. A similar project could be undertaken in India.[31]

THE PATH AHEAD

Over the years, the threat perceptions and the scope of military operations have changed. Space offers the fourth dimension of battle. Stratospheric flights are now more common. Low earth orbits are populated with communication and remote sensing satellites, some exclusively for military purposes. Technology, innovation and tactics aim at ensuring that airlift operations are never paralysed due to weather – an *all-weather* force is the ultimate aim. Space weather has, therefore, become a concern. The focus now is on space weather forecasting.

Weather and terrain will continue to affect airlift operations. Research and development will tell us more about the nature of these elements. Technology will present numerous better ways to deal with them. Even with today's technology, it may be possible to plot information on weather,

31. The source of this information on NGATS is a paper by H. Paul Stough of NASA Langley Research Centre, Hampton, Virginia, titled: *III Aircraft Weather Mitigation for the Next Generation Air Transportation System,* available http:// ntrs .nasa .gov/ archive/ nasa/ casi .ntrs .nasa .gov/ accessed May 17, 2011.

terrain, aircraft performance and aircrew category and visualise a three dimensional path for an aircraft that may be ideal to fly from a point on the map to another. It may also be possible to communicate midway alterations on the basis of real-time updates.

A common and striking feature of airlift operations dedicated to disaster relief missions is the unavailability of landing surfaces for large aircraft in the proximity of the affected people and areas. Most often, even the land routes are blocked and the only means of delivery of medicines, water and food, etc. are helicopters with limited capacity. Crucial time is lost as aid trickles in. In the case of the earthquake in Sikkim, the C-130Js positioned the relief teams and supplies at Bagdogra almost instantaneously but it took enormous effort in terms of helicopter sorties and road transportation to convey the specialists and the aid material to the epicentre near Gangtok, where they were urgently required. Future technologies will seek to airlift mega payloads regardless of the weather and terrain limitations. An Australian firm, Skylifter, is developing a large piloted airship that will carry up to 150 tonnes[32] of payload over a distance of 2,000 km. The airship will be able to carry rural hospitals and disaster relief centres to remote areas in different wind conditions.[33]

CONCLUSION

Weather and terrain are unavoidable elements of nature that influence all stages of airlift operations significantly. The domain of airlift operations integrates both natural and man-made elements. Yet, for long, there was a tendency to look at these elements as a somewhat isolated, tactical issue. Significant advances in technology are bringing about a shift from traditional, single point stand-up briefings towards continuously updated advice to the airlift formations at every step of mission planning and execution. Awareness has changed attitudes and approach. Weather and terrain now form part of doctrines and are given due importance.

32. This is nearly seven times the payload that can be carried by a C-130J Super Hercules and nearly double the capacity of a C-17 Globemaster.
33. "Giant Airship That Can Carry Entire Buildings 2000 km," *The Times of India*, October 06, 2010, p. 21.

Elements of nature are impartial to all users of the air space – friends and foes alike. Howsoever insignificant, nagging or irritating they may appear, their effects on airlift are consequential. Success of aerial delivery depends on availability of authentic real-time information and its analysis. There is need to be proactive rather than reactive to weather. The changed nature of modern warfare places extreme demands on the planners and those executing the operations. On the one hand, weather and terrain provide opportunities, and, on the other, they restrict opportunity.

Collection of information on terrain and weather within the country and on areas of interest outside the country must be a conscious and continuous process. Army patrols, Border Roads Origanisation (BRO) units, paramilitary forces, members of expeditions and any other organisations operating in physically inaccessible areas can provide valuable inputs for preparation of the intelligence folders on terrain and their weather patterns. Basic skills of obtaining data on terrain and weather for generating intelligence with a view to assist airlift operations could be included in the curriculum in the training establishments. Folders containing such information using data gathered judiciously and analysed by specialists can be prepared and will be of immense value in times of need. It must be borne in mind that the information contained in such folders would be required for instant use when time would be at a premium.

The effects of weather and terrain on airlift operations can be mitigated but cannot be eliminated completely. A side that can exploit the conditions stands a better chance of success. Technology enables collection and analysis of real-time data, which is most essential for mission planning. Yet an element of uncertainty is embedded in the calculations. Performance characteristics delivery aircraft and parachutes, training and capability of the aircrew and the para-troopers offset some of the ill effects of weather and terrain. Plans may not survive the first onslaught of bad weather but then preparedness is the key. All plans do not translate into reality due to the changing nature of weather. The effort must be to must build an ideology that stands the airlift forces in good stead in a majority of situations.

Trends suggest that it shall be possible, in the future, to gather relevant data through satellites, radars and infrared photography. Statistical methods shall enable meaningful analysis leading to selection of appropriate routes for the aircraft and for expeditious preparation of landing surfaces for aircraft operation. This will further support strategic decision-making and delivery of men and material any time, anywhere, despite the constraints posed by nature.