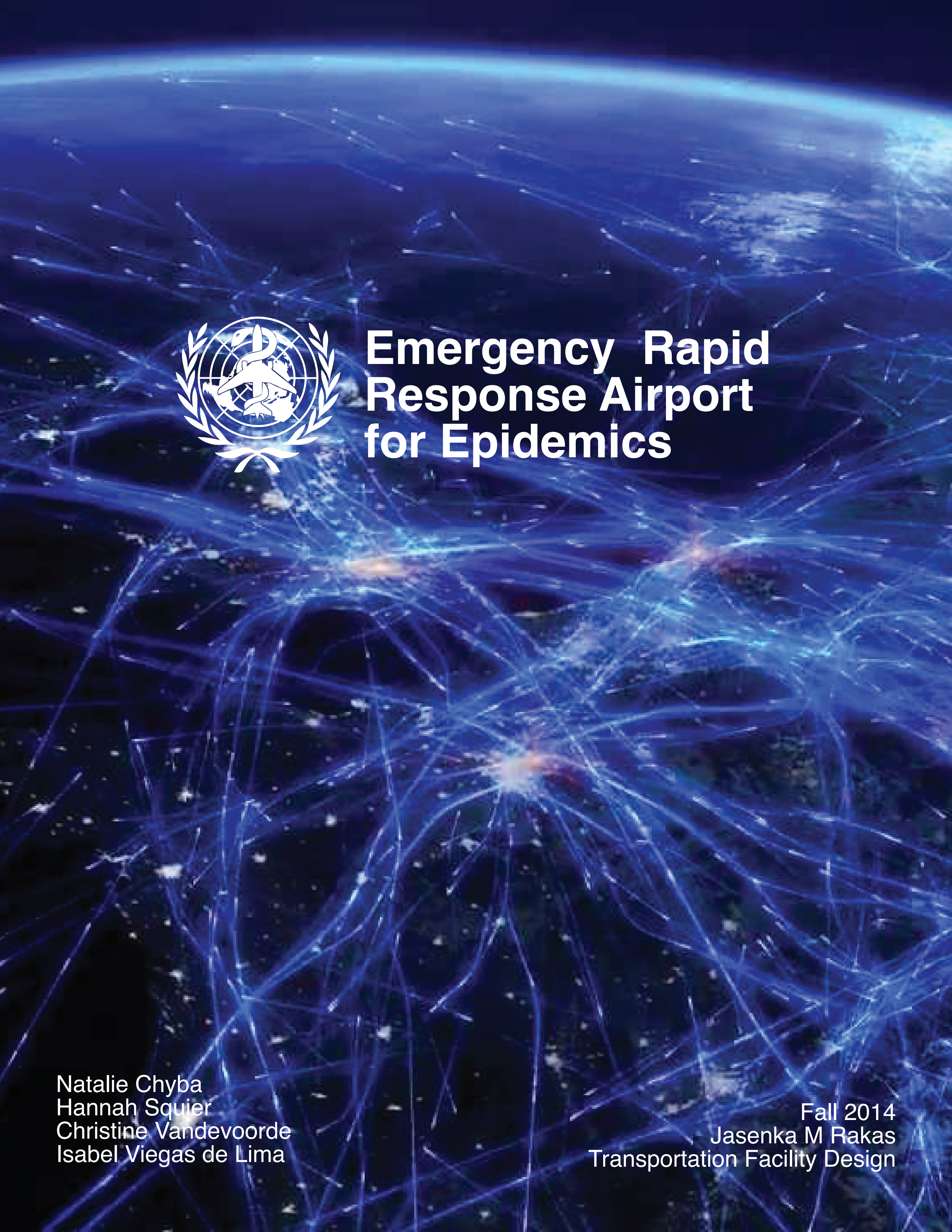

Emergency Rapid Response Airport for Epidemics

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This report provides the outline for an Emergency Rapid Response Airport (ERRA) for epidemics in rural regions. It establishes the World Health Organization as the operating organization with the Emergency Response Framework as the guiding document. After looking at different possible aircraft, the report recommends the use of civil tiltrotors and seaplanes. It outlines the required steps for selecting the site of the airport, assembling, operating, and disassembling the airport and also advises the use of a transponder landing system. Furthermore, the report specifies the organizational structures for health safety and security at the airport and provides a comprehensive framework for Personal Protective Equipment use for different types of epidemics. Finally, sample layouts of the airport are provided based on Federal Aviation Administration guidelines.

Table of Contents

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Introduction

In 2014, Ebola became one of the world's largest epidemics of the 21st century. As of December 24, 2014, 7,588 people have died from Ebola, with new cases each day ("Ebola Response Roadmap"). With Guinea, Sierra Leone, and Liberia, some of the world's poorest and least developed nations, at the forefront of the epidemic, the health emergency becomes exacerbated by lack of infrastructure. The hospitals are ill equipped, airports are crippled by their outdated infrastructure, and the roads are so poor that the World Health Organization (WHO) would rather charter flights than have their health workers navigate the roads to reach the affected population (Sheets).

According to WHO, twenty-five percent of the world's average of 700 annual technological and natural emergencies each year occur in less developed countries unprepared to tackle these emergencies (Emergency Response Framework). The hindrance of response due to accessibility issues during the Ebola outbreak is only one example of what is to come in future global health emergencies.

With statistics and examples such as these, it becomes clear that accessibility issues should be at the forefront of global health agendas and policies. More so, air transportation concerns should stand as a first priority, as the influx of supplies and the transport of aid workers and doctors remains a critical necessity for combatting these epidemics. Research must be done to analyze ways we can support less developed countries in the emergence of these global health crises.

Previous work has been done on assessing different air vehicles and their ability to respond to medical emergencies. A study done by Hotvedt et al. of the University Hospital of Tormsø, Norway looks at patients throughout different age groups from disparate locations to compare the impact of air-ambulance services on their gained life-years. Researchers found that, while there was a correlation with age groups, the major impact was experienced by rural patients (Hotvedt et al.).

We build on this research by approaching air transport not as an individualized means of treatment, but as a systematic response effort to mitigate the spread of disease and treat the affected population. We explore the idea of temporary, rapid response airports utilizing civil tiltrotors and seaplanes to deliver aid and transport workers and patients directly to and from the affected regions. The vehicle selection minimizes the necessary infrastructure, allowing for local resources to be utilized and for site-selection to be streamlined. This, along with other efforts, provides the fundamentals for an Emergency Rapid Response Airport (ERRA).

The following report outlines the steps taken to create our ERRA. It discusses the benefits of WHO as the operating organization, our vehicle and design decisions, operation protocols, and health and safety procedures. With every step, the critical function of servicing the affected region is addressed while keeping the primary constraint of rapid response in mind. This report serves as preliminary research for the use of airports in combatting epidemics and other natural disasters.

Please note that the mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by the authors of this report in preference to others of a similar nature that are not mentioned.

Operating Organization and Policy

To promote consistency and feasibility of our Emergency Rapid Response Airport, we decided it was necessary to identify an operating organization. The World Health Organization stands as a leader in world health, and with 194 Member States, has a reach that encompasses the entire globe. Its direct ties to the United Nations ensure its position in "shaping the health research agenda, setting norms and standards, articulating evidence-based policy options, providing technical support to countries, and monitoring and assessing health trends" ("About WHO"). Refined policies and regional offices all over the world make the World Health Organization (WHO) better equipped than any other agency to ensure emergency response is fully staffed, financially secure, and managed in a timely manner. With further research, we validated our immediate instinct to choose the World Health Organization as the operating entity of an ERRA.

Agencies and Organizations Considered

We decided on an operating entity for our ERRA by researching a few different globally respected emergency response organizations. The two that were most competitive with the World Health Organization, the International Federation of Red Cross and Red Crescent Societies and Doctors Without Borders, are summarized below.

International Federation of Red Cross and Red Crescent Societies

The International Federation of Red Cross and Red Crescent Societies (IFRC) serves as the world's largest volunteer-based humanitarian organization ("Principles and Rules…"). Its goal is to prevent human suffering wherever it may be found, whether in civil disputes, natural disasters, or epidemics. Its efforts range from education reform and humanitarian activism, to disaster mitigation. IFRC goals are commendable and they span the entire globe, with National Societies in 186 countries. The organization stands united to ensure that people of all backgrounds are guaranteed health, safety, and education.

IFRC organizational infrastructure is very similar to that of WHO, providing each region with a Vice-President to speak on the behalf of all regional National Societies, and an acting President elected by the Governing Board. Each National Society has a vote in all decision-making processes. While this organizational structure is conducive to quick and effective emergency relief, the National Societies do not have access to technically trained staff to handle the construction and operation of an Emergency Rapid Response Airport (ERRA) due to their entirely volunteer-based infrastructure. Primarily for this reason, the IFRC is not an appropriate ERRA operating agency.

Secondly, while emergency relief is a subsector of the IFRC's mission, world health is not its primary goal. For a program such as an ERRA, which requires extensive funding, it is required that the operating organization has the primary goal of global health to validate the allocation of resources and ensure the financial support of the airport.

Doctors Without Borders

Medecins Sans Frontieres (MSF), or Doctors Without Borders, has historically been one of the most aggressive and fast-acting responders to international health emergencies. The organization maintains this reputation by remaining an independent, neutral organization free of ties to any government or international regulation ("MSF USA…"). MSF's field team is comprised entirely of doctors, and its Association, the democratic element of the organization, is comprised of field doctors and office staff. Its primary focus is to provide on the ground aid and take an unbiased approach to treatment. Doctors Without Borders remains a strong and trustworthy voice on the progress of health emergencies all around the globe, and is looked to for advice by many larger international organizations, including the United Nations.

While MSF's opinion is valued due to its long held respect in the field, it has no say on health policies or influence over the governments of affected regions. MSF's lack of political influence was a significant drawback when we were deciding on the chief operating entity of our Emergency Rapid Response Airport, as such a program faces large administrative and political hurdles in addition to health and safety concerns. Further, Doctors Without Borders would face significant issues in staffing the airport as its staff and recruitment is focused primarily on medicine. While professionals from other fields are welcomed to assist with Doctors Without Borders' efforts, its expertise is not broad enough to operate an Emergency Rapid Response

Airport. Doctors Without Borders would not be suited to tackle the operation of an international airport, regardless of its pioneering skills in responding to health emergencies.

Administrative Benefits of WHO

The World Health Organization serves as the United Nation's (UN) leading global health organization. WHO was enacted under Article 57 of the Charter of the United Nations as a "specialized agency" ("Charter of the United Nations"). In 1946, all 51 Member States of the UN signed WHO's constitution, making it the first specialized agency with unanimous UN Member State participation. The World Health Organization now has 194 Member States, including all of the United Nations members, except for Liechenstein, and with the addition of Cook Islands and Niue.

The World Health Organization's direct affiliation with the United Nations gives the agency access to the governments of the affected regions and influence on policy decisions surrounding global health. Additionally, WHO has obligations to several international bodies and agreements related to emergency response to guarantee its leadership during the emergence of a global health crisis (Emergency Response Framework). These administrative benefits provide a space for an ERRA to be implemented.

The International Health Regulations

IHR and WHO

The International Health Regulations (IHR) is a set of guidelines created to provide fluidity in the prevention and response to health emergencies that have the potential to spread internationally. WHO is the author and guardian of the IHR, which went into effect in 2007. These regulations are binding across all 196 countries of the world. They provide a platform for all participating states to report events of potential human health risks to WHO in hopes of utilizing WHO's long history of preventing disease and promoting health ("International Health Regulations"). WHO serves as the operating entity for these regulations and is the key point of contact during any health emergency. While WHO has the ability to pass responsibility on to other more relevant intergovernmental agencies if it sees fit, it is primarily responsible for addressing any and all global health emergencies.

WHO's guardianship of the IHR promotes its unique ability to implement policy and create new regulations and recommendations where it sees fit. Due to its wide political influence, WHO serves as the optimal operating agency for an ERRA. Further, under the IHR, WHO has enough liberty, command, and responsibility to successfully operate an ERRA.

IHR and WHO as a space for an ERRA

An Emergency Rapid Response Airport is a solution for limited accessibility to regions affected by epidemics. If delivering supplies and providing transportation is not feasible, the affected Member States and WHO are mandated by the IHR to work together to ensure the issue is addressed; "WHO shall collaborate in the response to public health risks and other events by providing technical guidance and assistance and by assessing the effectiveness of the control measures in place, including the mobilization of international teams of experts for on-site assistance, when necessary" (International Health Regulations, 2nd Edition).

Several administrative issues must be considered and addressed before a project as multifaceted as an ERRA can begin. These issues and concerns can be tackled by implementing procedures outlined in the IHR.

The first issue considered is the enormous amount of communication necessary for an emergency response airport to be implemented successfully. An ERRA is to operate as a central hub for transportation of affected patients and as a supply pipeline for medical equipment, personal protective equipment, food, water, and resources. For an ERRA to be implemented, the epidemic at hand would likely be severe enough to have several intergovernmental organizations involved on the ground. The airport should service all competent intergovernmental organizations in the affected area, and thus require inter-organizational communications. Under the IHR, WHO is required to "cooperate and coordinate its activities, as appropriate, with other competent intergovernmental organizations or international bodies in the implementation of these Regulations…", in which the IFRC, International Civil Aviation Organization (ICAO), and International Air Transport Association (IATA) are all considered "competent intergovernmental organizations" (International Health Regulations, 2nd Edition). Thus, we conclude an ERRA would have an adequate communication network required to operate the airport, distribute goods, and provide transport services to patients being treated in various locations. Additionally, if WHO deems it can only provide consultation on operations, and not head ground operations, the IHR states that, "In cases in which notification or verification of, or response to, an event is primarily within the competence of other intergovernmental organizations or international bodies, WHO shall coordinate activities with such organizations or bodies in order to ensure the application of adequate measures for the protection of public health." If necessary, WHO shall pass the operation of the airport onto an organization they see fit.

The second issue of concern is allocating airspace and managing air traffic control for the ERRA. Because airspace over less developed countries is not as carefully regulated, it is of great importance that the Emergency Response Team operating the airport has open communication with the closest regional air traffic management system to obtain flight clearance for the aircraft. WHO's relationship with ICAO, facilitated by the IHR, can guarantee that such communication remains constant and can assist in traversing complex international airspace and navigation regulations. More on air traffic control can be found in the Operations and Logistics section of this report.

The third issue that may arise is Member States resisting a temporary port being built, which would threaten the implementation of an ERRA, and thus severely limit accessibility to regions affected by the epidemic. Due to the legal nature of the IHR, WHO Member States are bound to certain requirements that address accessibility concerns during an emergency and encourage cooperation with WHO. First and foremost, the IHR urges Member States to "collaborate actively with each other and WHO" in accordance with detailed regulations to ensure effective emergency response (International Health Regulations, 2nd Edition). If the affected regions' airports do not meet the requirements presented in Annex A of the IHR, authorities are neglecting the legal obligation of the IHR and must collaborate with WHO to establish an airport that meets these requirements. An ERRA implemented by WHO can provide temporary relief for regions that do not have access to an airport that abides by IHR accessibility standards.

World Health Organization Leadership and Work Breakdown Structure

When the United Nations wrote WHO's constitution, it mimicked its own organization breakdown structure. Like the United Nations, WHO is operated by an assembly made up of delegates from Member States. This assembly is known as The World Health Assembly (Health Assembly) and is responsible for the operation of WHO. The Health Assembly determines the policies of the Organization, elects members to the Executive Board, appoints the Director-General, establishes committees, reviews and approves reports, and coordinates with the UN on all financial matters. The Executive Board (The Board) was created in order to ensure implementation of all regulations and policies the Health Assembly puts into effect. As stated in the constitution, the Board is the "executive organ of the Health Assembly" (World Health Organization Constitution). The Board's most relevant role in the administration of an ERRA is its responsibility "to take emergency measures with the function and financial resources of the Organization to deal with events requiring immediate action. In particular it may authorize the Director-General to take the necessary steps to combat epidemics" (World Health Organization Constitution). Finally, under the Board is the Secretariat. The Secretariat is comprised of the Director-General and all technical and administrative staff WHO needs to operate.

The Director-General is the chief technical and administrative officer of WHO. The Director-General can establish "a procedure by agreement with Members, permitting him, for the purpose of discharging his duties, to have direct access to their various departments, especially to their health administrations and to national health organizations, governmental or non-governmental. He may also establish direct relations with the international organization whose activities come within the competence of the Organization" (World Health Organization Constitution). His role enables him to be the chief administrative officer for the implementation of an ERRA, as he has the ability to coordinate with Member States to ensure its necessity, handle the relationship with ICAO to follow flight rules and regulations, and delegate resources.

The Director-General's office is in WHO Headquarters, thus he is physically removed from the locations of conflict. Regional Offices were created to address this issue, providing the Director-General with administrative and technical staff who are experienced in the region of concern.

The Regional Offices' primary benefit is to assist with the relationship of Member States' government officials and to navigate the various cultures of the world. Regional Offices' organizational structure mimics that of Headquarters, with a Regional Director as the main point of contact and chief officer.

Refer to Appendix A-1 for an Organization Breakdown Structure of WHO.

Emergency Leadership Breakdown

In 2011, WHO created the Global Emergency Management Team (GEMT). The GEMT's purpose is to lead the emergency work efforts of WHO. It is comprised of all relevant Directors from Headquarters and Regional Offices. If there is an issue of concern unfamiliar to the members of the GEMT, they may call on all members of the Global Emergency Network for assistance. The Global Emergency Network includes all directors of all programs operated by WHO. During an emergency, a team of relevant Directors makes up the GEMT-Response (GEMT-R). A description of GEMT-R's role in an emergency is further analyzed below in WHO's Global Emergency Management Team subsection.

On the ground, the Emergency Response Team (ERT) tackles the emergency. The ERT is comprised of repurposed country office staff until experienced staff can be sent out by the GEMT-R. The ERT is lead by the Health Emergency Leader (HL) during Grade 3 emergencies, and by the Head of WHO Country Office (HWCO) during Grade 1 or 2 emergencies. The HL is a member of the GEMT-R. Further, an Emergency Support Team falls under the ERT to provide support during the emergency.

During an emergency qualified for the implementation of an ERRA, the GEMT-R will recommend it to the Director-General if the program will be of use. Once the ERRA is approved, a technical team deployed by the GEMT-R under the ERT will select a site and design, assemble, operate, maintain, and finally disassemble the ERRA. This technical team will be referred to as the "operations team" of the ERRA in this report.

Please refer to Appendix A-2 for an organizational breakdown structure of Emergency Teams.

WHO's Emergency Response Framework

In 2013 WHO released their Emergency Response Framework (ERF) with the intent to further clarify its role and procedures in the event of a health emergency. The ERF outlines WHO's core commitments, event verification and event risk assessment, internal grading process, performance standards, four critical functions during an emergency, Global Emergency Management Team, procedures, and essential emergency policies. While this framework does not include a plan for the implementation of emergency transportation, it states the importance of access to the affected population for a successful implementation of the ERF. This provides the space for a program such as an ERRA to be integrated into relief efforts if deemed necessary by the Director-General.

Core Commitments in Emergency Response

WHO's core commitments in responding to any form of emergency with public health consequences are focused around implementing strategies, maintaining communication with the Member State affected, and monitoring progress at all times. They are as follows:

1. Develop an evidence-based health sector response strategy, plan and appeal;
2. ensure that adapted disease surveillance, early warning and response systems are in place;
3. provide up-to-date information on the health situation and health sector performance;
4. promote and monitor the application of standards and best practices; and
5. provide relevant technical expertise to affected Member States and all relevant stakeholders. (Emergency Response Framework)

If inaccessibility to the affected population or obstruction of aid delivery hinders the response to the public health emergency, an ERRA can be implemented as a "response system" under the core commitments of WHO.

Event Verification and Event Risk Assessment

Event Verification and Event Risk Assessment provides WHO with a framework to analyze an event's severity and gives a timeline for the classification process of an event. For the purpose of our research, this framework proves most useful in the analysis of slow-onset events, a classification that includes epidemics. Slow-onset events can be difficult to assess due to their lack of a “trigger point”, or the point at which conducting an event risk assessment is necessary.

In the case of a slow-onset event, event verification and risk assessment can be triggered by new information becoming available, new developments (ex. in urgency or complexity or political, social, or economic changes), and new perceptions (ex. Heightened international media coverage, member state concerns, or UN and NGO involvement and grading). When the trigger point is identified and event verification and risk assessment is underway, the event is analyzed under two criteria: scale and urgency. The scale of an event considers both the direct and indirect effects of the event on a region. Direct effects include the number of affected people and level of severity of the disease at hand, with priority placed on “vulnerable and marginalized groups” and regions with poor health care facilities (Emergency Response Framework). Indirect effects cover the event’s effect on trade and travel, as well as the event’s deviation from predictable events. The assessment of the “urgency” of an event analyzes the disease itself rather than the impact of that disease. Urgency considers the threat of mortality, transmissibility, and international spread. The assessment of both the scale and urgency must be completed within 48 hours after determining it is necessary.

An ERRA may be worked into the strategic response plan if the assessments deem an event severe enough to warrant a WHO response. In this case, those responsible for the risk assessment must notify all appropriate parties (Headquarters, Regional Directors, and the Global Emergency Management Team) within five days. Further, the Directors at Headquarters who are part of the Global Emergency Response Team must convene via teleconference to review the results of the assessment and determine if grading is necessary (“WHO Internal Grading Process” below). WHO must notify any affected Member State immediately following the event risk assessment. The event is closed when the Global Emergency Response Team deems a WHO response is no longer necessary.

Assessment paths for sudden-onset events, events not requiring a WHO response, and those deemed a potential risk are not outlined here due to their lack of relevance to our research on epidemic related emergencies. Information on these events can be found in the Emergency Response Framework.

WHO Internal Grading Process

The purpose of WHO's internal grading process is to have a procedure in place that ensures accurate technical, financial, and human resource allocation to an event based on its severity. The grading process allows for all events to be classified into three categories, Grade 1, 2, or 3, to promote streamlined emergency response.

The grading must occur within 5 days of the risk assessment's completion for slow-onset events and is determined by reviewing the scale, urgency, complexity, and context of the event. The scale and urgency are completed during risk assessment, while the complexity and context are reviewed after the level of risk has been determined. Complexity considers "the range of health consequences", including the technical skillset required to tackle the emergency, political issues, concurrent emergencies, and other indirect effects of the event (Emergency Response Framework). Context considers the environment in which the event is occurring, public response to the event, and the local government's level of preparedness.

The grades and their appropriate responses are summarized in Appendix A-3 and A-4 respectively.

The removal of a grade will be done when the "acute phase of an emergency has ended" and the Directors at Headquarters responsible for the event have announced the removal (Emergency Response Framework). The removal is estimated to occur three months after the initial grading. If more time is needed, there will be a restructuring of resources to ensure continuous support to address the health emergency.

An ERRA is implemented under a Grade 3 event only, as the access to financial resources must be vast and the No-Regrets policy (see section on Essential Policies for Optimizing WHO's Emergency Response) must be in effect in order for a successful implementation of such a program. Further, for the purpose of our preliminary research, it will be assumed the grade is removed after three months.

WHO's Performance Standards

WHO's performance standards "ensure an effective and timely health sector response" and are applied for health emergencies falling under every grade (Emergency Response Framework). For sudden-onset events, the performance standards are broken up in the following timeline taken from WHO's ERF and go into action immediately following the grade. For slow-onset events, such as one for which an ERRA would be necessary, the timeline fluctuates based on the need called for by the GEMT-R.

Within 12 Hours

1. Designate WHO emergency focal point and share contact details with relevant staff throughout the Organization.
2. Repurpose WHO country office (WCO) and/or other relevant offices, mobilizing its existing staff to form the Emergency Response Team (ERT), to initially perform WHO's four critical functions in emergency response, and to deliver on the first Performance Standards, until the emergency grade is removed, or until the staff are replaced by newly arriving (deployed) staff.

Within 48 Hours

3. Ensure a continuous WHO presence at the site of the emergency and make initial contact with local authorities and partners (or as soon as access is possible).
4. Negotiate access and clearances with the government (where relevant) on behalf of health sector partners (and then on-going).
5. Make widely available the preliminary health sector analysis based on the most recent event risk assessment.
6. Compile and produce the first situation report (using a standard format), media brief and other communications and advocacy product relevant to the emergency.

Within 72 Hours

7. Ensure the arrival in-country of a team of experienced professionals to reinforce or replace the repurposed WCO staff to fulfill WHO's four critical functions as part of WHO's Emergency Response Team (ERT). In a Grade 3, and possibly in a Grade 2, a Health Emergency Leader (HL) is deployed on a no-regrets basis to lead the ERT.
8. Establish and deliver emergency administrative, human resources, finance, grant management and logistics services (and then on-going).
9. Establish health sector/cluster leadership and coordination; conduct a health sector/cluster meeting; update the 4W matrix (a database of who is doing what where and when), and plan next steps.
10. Represent WHO and the health sector/cluster at meetings of the UN Country Team (UNCT), Humanitarian Country Team (HCT), inter-sector/cluster coordination and other relevant sectors/clusters (such as water/sanitation/hygiene, logistics and nutrition), (and then on-going).
11. Use preliminary health sector analysis to identify major health risks and health sector objectives and priorities for the first three months, including potential downstream public health consequences.
12. Engage health sector partners to participate in a joint health assessment as part of a multisectoral process (see 21 below).

Within 5 Days

13. Develop a flexible, short-term sector response strategy and action plan, in collaboration with the Ministry of Health (MoH) and partners that addresses health needs, risks and capacities, with appropriate preventive and control interventions, for the first three months (and then review and update as required).

Within 7 Days

14. Develop, in collaboration with the MoH and partners, a funding appeal, if required (revise it at 30 days and as necessary thereafter)
15. Provide coordinated, specialized, international technical assistance as required, including logistics for implementation of prevention and control interventions (and then on-going).

16. Adapt/strengthen surveillance and early warning systems for diseases and other health consequences in the affected area (or ensure its establishment within 14 days), and produce the first weekly epidemiological bulletin.
17. Promote and monitor the application of national, and where applicable, international, protocols, health standards, methodologies, tools and best practices (e.g. IHR, other WHO, Global Health Cluster, IASC, SPHERE), (and then on-going, as required).
18. Compile and produce a second situation report, media brief and other communications and advocacy products relevant to the emergency (and then on-going at least twice per week).
19. Monitor and share relevant information for decision–making on health indicators, using appropriate parameters of measurement, (and then weekly).
20. Monitor the response of the health sector and address gaps in implementation of prevention and control measures, service delivery and cluster leadership (and then weekly).

Within 15 Days

21. Make widely available the results of the joint health assessment (see 12 above).

Within 60 Days

22. Lead the health sector/cluster in conducting an in-depth health-specific assessment (after day 15 and before day 60).
23. Develop a health sector transition strategy from response to recovery, in collaboration with MoH and partners.

If accessibility issues become evident when negotiating with the local government (4), the GEMT-R begins considering the possibility of implementing an ERRA. If an ERRA is recommended to the Director-General and approved, it is worked in to the response strategy developed soon after (13). If the ERRA is not recognized as necessary so soon into the development of the event, the Health Emergency Leader may implement it later using the No-Regrets Policy (see section on Essential Policies for Optimizing WHO’s Emergency Response).

WHO's Four Critical Functions

To guarantee delivery of WHO's core commitments and Performance Standards, WHO Country Office in which the emergency is occurring will deploy an Emergency Response Team (ERT). In a Grade 3 emergency, a pre-qualified Health Emergency Leader will be assigned to manage the ERT.

The Four Critical Functions are as follows:

Leadership | Provide leadership and coordination of the health sector/cluster response in support of the national and local health authorities.

Information | Coordinate the collection, analysis and dissemination/communication of essential information on health risks, needs, health sector response, gaps and performance.

Technical Expertise | Provide technical assistance appropriate to the health needs of the emergency (including the provision of health policy and strategy advice, promotion of expert technical guidelines, standards and protocols, best practices, and implementation/strengthening of disease surveillance and disease early warning systems); WHO will always work to ensure the provision of health services through partners and, as a last resort, will take measures to cover the critical gaps, for example through mobile clinics or other interventions.

Core Services | Ensure logistics, office establishment, surge and human resources management, procurement and supply management, administration, finance and grant management.

If accessibility issues arise when negotiating with the local government (see 4 of Performance Standards above) and the emergency warrants an immediate international and WHO response, an Emergency Rapid Response Airport is suggested to mitigate the situation. If deemed necessary by the Director-General, the Health Emergency Leader may put together a pre-qualified technical team to manage the set-up, operation, and disassembly of the ERRA.

WHO's Global Emergency Response Team

The Global Emergency Response Team (GEMT) was set up by WHO in 2011 to lead the efforts of WHO's emergency work. The GEMT is made up of all relevant Directors, both in Headquarters and Regional Offices. They work constantly to ensure all regions are prepared and ready to respond if an emergency arises, whether suddenly or slowly. While the GEMT's expertise lies in all-hazards emergency risk management, they may seek advice from various heads of departments and programs for specific technical concerns.

When emergency response becomes necessary, the GEMT puts together a Response Team (or GEMT-R). This Response Team is comprised of the appropriate Directors in the affected regions and comes together to assess and grade the emergency, and prepare for an international response.

During a Grade 3 emergency, the GEMT-R sector of WHO is responsible for stressing the necessity of an Emergency Rapid Response Airport to upper management. Once given the okay to proceed, all administrative and coordination efforts are done through the GEMT-R. This includes repurposing the Emergency Response Team on the ground to ensure a technical team is in place for its implementation, working with the local government and other international organizations on site-selection, and putting together funds.

Essential Policies for Optimizing WHO's Emergency Response

The Surge and No-Regrets Policies go into effect during Grade 2 and 3 emergencies to ensure that every international health emergency is responded to quickly and with the appropriate resources.

Surge Policy | The Surge Policy is in place to properly staff an emergency. The Surge Team 1 is comprised of pre-identified, trained, and experienced professionals sent to the region to assist and/or replace members of the WCO that were reassigned to the Emergency Response Team. The Health Emergency Leader may be a part of this phase in the surge. Surge Team 2 is deployed within two weeks from grading and is comprised of professionals from WHO and partner organizations to reinforce the existing ERT. After 12 weeks, the Regional Office must have a permanent long-term staff in mind, and all unnecessary surge team personnel are relieved and all repurposed WCO members may go back to their previous positions. While the surge policy may result in superfluous emergency responders, the mindset of WHO is that to properly mitigate the effects of an emergency, a team may need to be overstaffed to insure it is never understaffed (Emergency Response Framework).

No-Regrets Policy | WHO ensures that predictable levels of funding and staffing are met without blame or regret even if it is later realized that not all resources were necessary. This approach, known as the No-Regrets Policy, was put in place to err on the side of caution, by over-resourcing critical events, rather than risking failure by under-resourcing. By placing no limit on responders, the no-regrets policy allows room for the surge policy. In terms of funding, the no-regrets policy states that the Health Emergency Leader may allocate up to $500,000 to the emergency without having to obtain prior approval during the first three months of the response (Emergency Response Framework). While more can be spent, after exceeding $500,000 normal WHO expenditure procedures must be followed.

The Surge Policy and the No-Regrets Policy together take care of concerns regarding staffing and funding for an Emergency Rapid Response Airport. If accessibility inhibits the Emergency Response Team from completing its critical functions or performance standards, the GEMT-R and the Health Emergency Leader can put together a team and allocate funding for assembly of an ERRA.

Vehicle

Previous work has been done on assessing different air vehicles and their ability to respond to medical emergencies. According to Hotvedt et al. of the University Hospital of Tormsø, Norway, rural patients are the ones who benefit the most from aircraft emergency response, especially through helicopters. The study looks at the patients throughout different age groups from disparate locations to compare the impact of air-ambulance services on their gained life-years. Researchers found that, while there was a correlation with age groups, the major impact was experienced by rural patients. This happens because they are able to receive services on the aircraft and reach a hospital in a timelier manner (Hotvedt et al.).

A study conducted by the University of Vermont on unmanned aircraft systems (UAS) has shown the potential of using UAS in emergency relief. The researchers analyzed Big Data from secondary literature on medical applications of UAS to look at frequency of occurrence, time-sensitivity of occurrence, complexity of terrain, financial impact, and cultural acceptance. They found that, while UAS were effective in responding in a timely manner and in difficult terrain, the cost of operations went up significantly as the situation became more time-sensitive (Spitberg and Jones).

Comparing Potential Vehicles

When selecting the aircraft for an Emergency Rapid Response Airport (ERRA), we looked at the capacity, the availability, and the range of the aircraft as well as the compatibility of the aircraft infrastructure with a rapid response timeline and available resources. Fuel usage and cost were not major factors in the selection of aircraft because of the No-Regrets policy established by WHO as discussed in this report.

Commercial Jet

The first aircraft we looked at was the most commonly and commercially available: commercial jets. While a Cessna, for example, can carry up to twelve passengers and travel up to 7,400 km, or 4,000 NM—far enough to reach another airport to refuel or a hospital—the jet requires a runway to take off and land ("Cessna Aircraft Company"). Therefore, using jets would necessitate an appropriate runway to be built, which is incompatible with the rapid response goal of an ERRA. While it may be possible to build a runway if the affected region was in an urban environment containing the appropriate supplies, the required materials and pre-construction infrastructure required is too complex for rural areas—especially one with dense terrain.

Helicopter

Helicopters are a valid option for our needs based on the speed of their response and the infrastructure they require. Further, their take off and landing space requirements are far less than that of commercial jets. While an airplane requires a whole runway, helicopters simply need a helipad, being a Vertical Take-Off Landing (VTOL) aircraft. This setup does not require the resources needed to build a runway and decreases the overall area that must be cleared for an ERRA, which in turn reduces construction time.

On the other hand, helicopters pose considerable issues when it comes to their capacity and range. Most non-military helicopters are limited in their cargo and/or passenger space. Since we are trying to increase mobility of the exposed and affected people, we looked at high capacity helicopter options. Airbus Helicopters, for example, are capable of passenger transportation and casualty evacuation. Their passenger transportation helicopter can carry up to two pilots and twelve passengers and their casualty evacuation helicopter can carry two pilots, two stretchers, and four additional passengers. While the capacity of these large helicopters is better than that of conventional ones, the average range of these helicopters—including the auxiliary tanks—is only 923 km, or 498 NM, which is not enough for our purposes ("Dauphine Airbus Helicopters"). For an aircraft to meet our requirements, it must be able to fly far enough to reach a larger airport to refuel.

Unmanned Emergency Response Aircraft

Unmanned aircraft systems (UAS) have increasingly been used in remote locations where piloting other types of aircraft prove too complex. According to a study performed by Spitsberg and Jones, UAS have the added advantage of responding quickly and in hard-access areas. Furthermore, in the case of emergency response to epidemics, UAS would be beneficial because it would reduce the number of people exposed to the disease. In terms of capacity and range, UAS are constructed in a variety of manners and can therefore be designed to meet our needs. However, availability and cultural acceptance of unmanned vehicles make UAS a non-desirable vehicle to use. Due to military and personal usage, unmanned vehicles—also known as drones—have an increased negative public opinion and have been the subject of toughened legislation inside the United States. California AB 1327, for example, limits the situations in which drones may be used by law enforcement (Terdiman).

Another important aspect of UAS is the availability of vehicles that would work in the limited-resources scenarios that we have. A drone that would be able to carry a sufficient number of passengers would require a runway, which, as mentioned above, is a piece of infrastructure we would like to avoid. While VTOL UAS do exist, they are not yet commercially available for the size and range we require ("VTOL UAV & Multirotor Manufacturers"). Thus, UAS as they are manufactured today are not feasible selections for the ERRA.

Civil Tiltrotor

Civil tiltrotors are a good candidate for an ERRA. Like the helicopter, the civil tiltrotor is a VTOL aircraft and therefore requires reduced infrastructure as a runway is replaced by a vertistop. This reduced infrastructure translates into a smaller amount of required natural resources and the ability to use more accessible resources. Therefore, a vertistop translates to a more accessible, smaller amount of resources needed, as concrete and asphalt may be substituted. According to a Federal Aviation Administration (FAA) Advisory Circular, the Touchdown and Lift-Off Surface (TLOF) simply needs to be a paved or hard surface that can withstand the weight of the aircraft ("Advisory Circular: Vertiport Design"). This vastly increases the array of permissible natural resources that can be used, making it more applicable to diverse parts of the world. Additionally, the area that needs to be cleared out for the construction is considerably smaller, making the setup easier and more environmentally sound.

While the passenger capacity of tiltrotors is in the magnitude of that of the Airbus Helicopters, the range of travel is considerably higher. This distinction from the helicopter made the civil tiltrotor a more viable option. Commercially available civil tiltrotors can reach almost twice the range of helicopters on standard fuel tanks. While helicopters are unviable because they can not reach larger airports for drop-off or refueling, the civil tiltrotor has enough fuel to make such trips—especially if an auxiliary tank is added.

We selected civil tiltrotors as one of our possible aircrafts for an ERRA because of its capacity and range as well as its advantageous VTOL infrastructure.

Seaplane

Seaplanes were also an appropriate alternative for an ERRA. In the case of the emergency site being situated near a river or a large body of water, we can save considerable time and resources in putting together the ERRA by employing seaplanes. Seaplanes are able to take off and land without a runway, making them very attractive to regions where the resources required to build a paved vertistop are not locally or politically accessible. Their versatility is also favorable in densely forested areas where deforestation and clearing to construct the airport would require more manpower, money, and time.

Other than their practical landing operation, seaplanes are also favorable in other aspects. The capacity of seaplanes can vary from only the pilots, to the pilots and ten additional passengers. This makes them a viable solution for transporting affected people and supplies. Furthermore, the range of seaplanes exceeds 2,000 km, or 1,100 NM, greater than that of the other options assessed.

The seaplane is a great option for locations near a large body of water because of its capacity, range, and lack of runway. If it were not for the geographic limitations of possible epidemic locations, it would be the ideal option for all scenarios.

Choosing Models

After deciding on civil tiltrotors and seaplanes, we chose a commercially available model for each on which to base our designs and operations. While we thought it would be beneficial to provide possible models that would fit the provided designs, the aircrafts mentioned here are in no way the only ones available.

Civil Tiltrotor | AgustaWestland's AW609

AugustaWestland is an Anglo-Italian company in the vertical lift market. Although they specialize in helicopters, the AW609 is a commercially available civil tiltrotor. The aircraft can travel up to 700 NM on a standard fuel tank and can carry two crew members and nine passengers. It travels at 275 knots, which is almost twice the speed of a typical helicopter at 140 knots. The AW609 is ideal for our needs because, since it is a VTOL, it requires only a vertistop instead of a runway ("Products: Tiltrotor").

The specified dimensions and design below were taken from the informational pamphlet available on the AugustaWestland website.

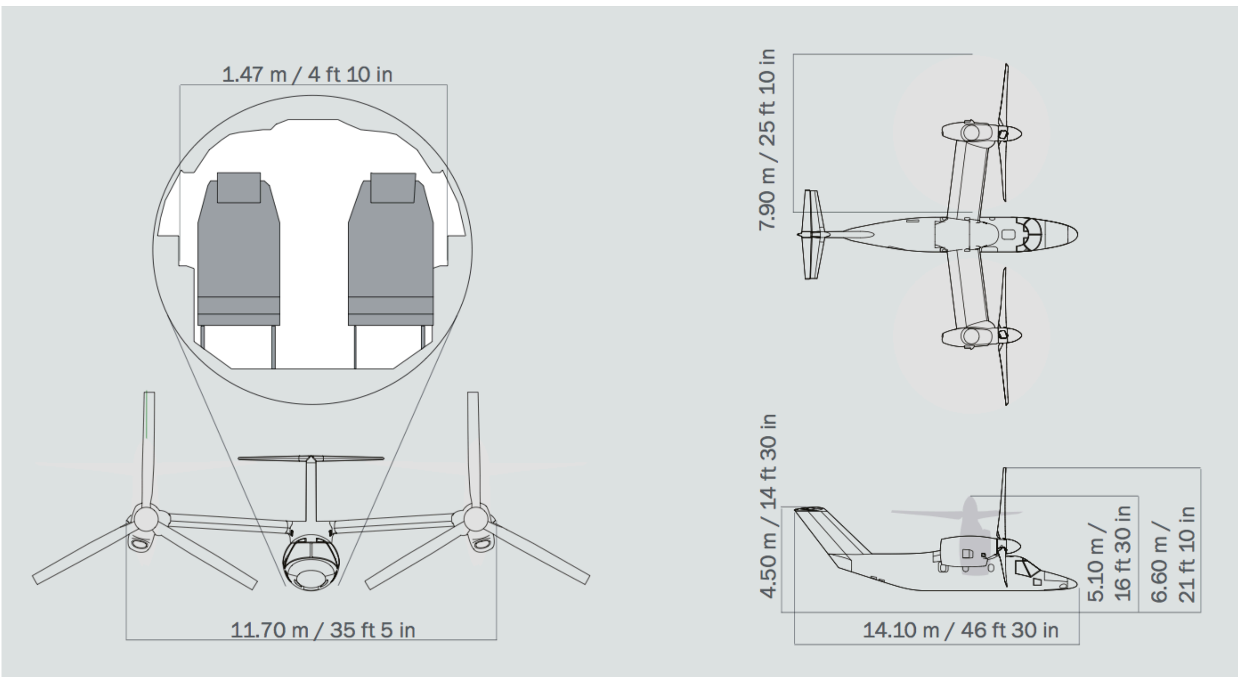


Figure 1: AW609 Side, Front, and Top Views

Seaplane | Antilles Seaplanes' Model G-21G

Antilles Seaplanes LLC is a company from North Carolina that produces seaplanes. Their primary aircraft in production is the Model G-21G, which is capable of landing both on runways and in water. The seaplane can travel 2,221 km, or 1,200 NM, and can hold up to two pilots and six passengers ("Antilles Seaplane Model G-21G").

The following figures were retrieved from the Antilles Seaplanes website and contain the design for the aircraft.

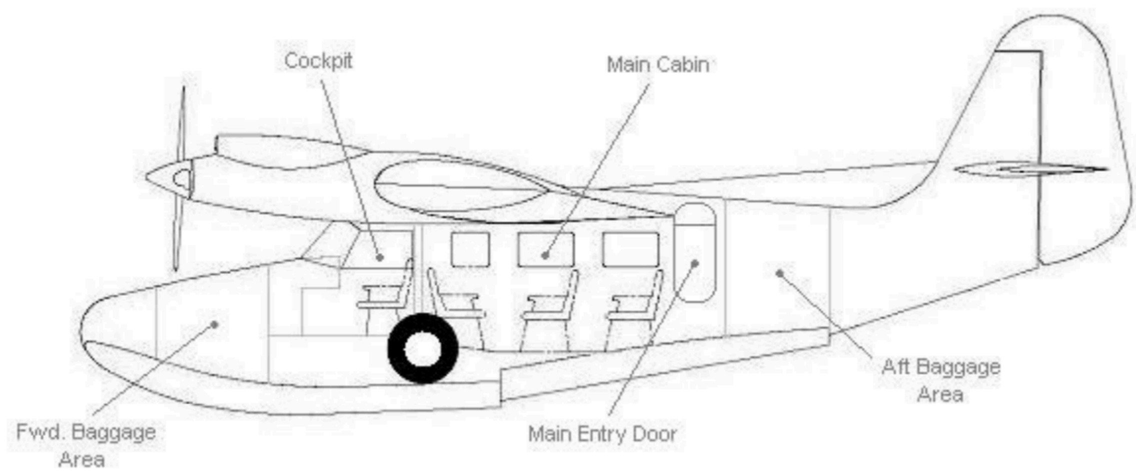


Figure 2: Antilles Seaplane Model G-21G Side View (Profile)

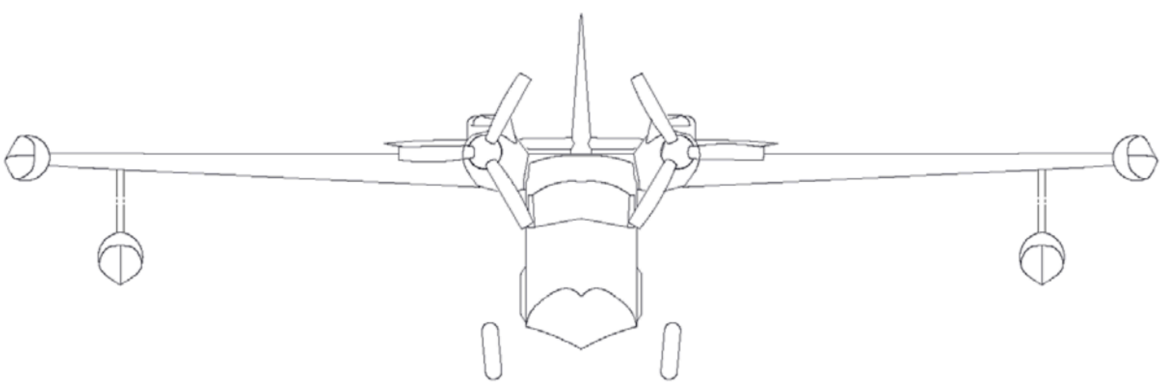


Figure 3: Antilles Seaplane Model G-21G Front View

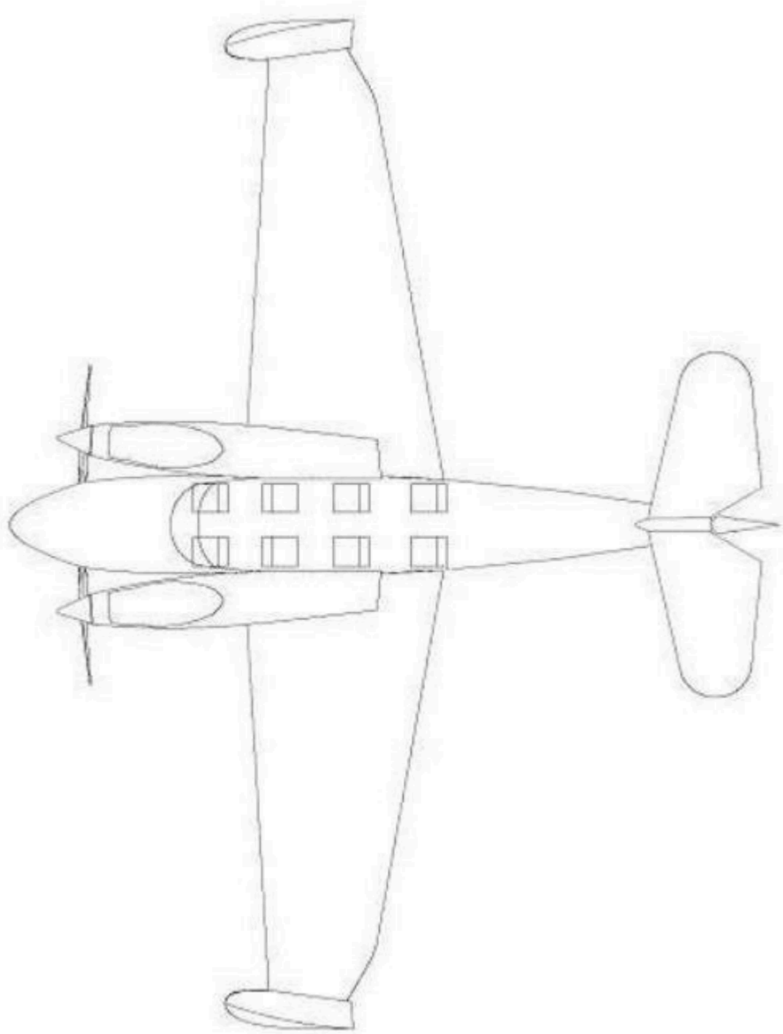


Figure 4: Antilles Seaplane Model G-21G Top View (Plan Form)

Operations and Logistics

The operations team at an Emergency Rapid Response Airport (ERRA) has two primary areas of responsibility: air traffic control and on-the-ground emergency response management. Thus, an ERRA operations team must be accountable to both the International Civil Aviation Organization (ICAO) and the World Health Organization (WHO) in that it must meet ICAO standards for aircraft operations safety as well as work within the emergency response framework of WHO. The operations team is comprised of pre-qualified Emergency Response Team members selected by the GEMT-R.

According to ICAO, operations is defined as "the flying of the airplane, the control and/or monitoring of the aircraft by the air traffic management system, and the conduct of various airport activities" ("Operational Measures"). In the context of an ERRA, the responsibility of the operations team is to select, set up, operate, and maintain the proper navigation, surveillance, and communications equipment to maintain aircraft flight safety when taking off and landing and to assist the pilot in obtaining flight clearance from the closest regional air traffic management system.

Responsibilities

The operations team reports directly to and is in constant communication with the Health Emergency Leader put in place by the GEMT-R. According to WHO, the responsibilities of a GEMT-R are to "ensure optimal use of resources, monitor implementation of relevant procedures and policies, and manage internal and external communications" (Emergency Response Framework). Using this definition of a GEMT-R and adapting the responsibilities specifically to an ERRA in the case of epidemics in rural regions, the GEMT-R utilizes the operations team to act on the following responsibilities:

Ensure optimal use of resources

1. Maintain an inventory of essential supplies: food, water, medical supplies, tents, fire extinguishers, aircraft fuel, and technological equipment (detailed in the "Technological Requirements" section below).
2. Ensure adequate staffing of the ERRA: medics, air traffic controllers, mechanics, construction managers and laborers (during the assembly and disassembly phases of

the ERRA), security guards, and representatives from the local government (if deemed necessary).

Implementation of Relevant Procedures and Policies

1. Oversee the four phases of the ERRA implementation: site selection, assembly, operations, and disassembly (detailed in "Phases of Implementation" section below).
2. Regulate the inflow and outflow of people so as to not exceed the capacity of the ERRA facilities.
3. Maintain the security of the ERRA (detailed in the "Security" section below).
4. Maintain health records of all persons entering and leaving the ERRA.
5. Ensure quarantining or isolation of affected persons (detailed in the "Health" section below).
6. Implement a procedure for waste management (detailed in the "Health" section below).
7. Provide emergency medical care if necessary (detailed in the "Health" section below).
8. Distribute food, water, and supplies to all persons.
9. Select, set up, operate, and maintain required technical equipment.
10. Establish a work breakdown structure to ensure all team members are aware of their individual responsibilities.

Manage internal and external communications

1. Air-to-ground communication
2. Ground-to-ground communication within the ERRA
3. Ground-to-ground communication between the ERRA operations team, the WHO Country Office, and the chosen IHR focal point within the local government (International Health Regulations, 2nd Edition).
4. Ground-to-ground communication between the ERRA operations team and the nearest regional air traffic management center

Guiding Principles

The following portions of the operations section evaluate the required technological equipment of an ERRA as well as the procedures for the four phases of implementation of an ERRA. There are five guiding principles that inform the evaluation of technological options and the implementation of the four phases of an ERRA. First, the ERRA is designed to be assembled in the shortest amount of time possible without sacrificing safety. This is achieved by minimizing the use of ground-based equipment, by selecting equipment that can be installed quickly, and by selecting aircraft with minimal required on-the-ground infrastructure. Second, because WHO operates under the No-Regrets policy during Grade 3 emergencies, cost is not a major consideration in the selection of equipment (Emergency Response Framework). Third, the ERRA is designed to accommodate low traffic only due to its rural location. Fourth, the ERRA is designed to be permanent enough to sustain operations for at least three months; after three months, the necessity of the ERRA should be re-evaluated by WHO in accordance with its guidelines (Emergency Response Framework). Fifth, it is important to err on the conservative side when evaluating technological equipment. For example, instrument meteorological conditions (IMC) are assumed so that an ERRA can accommodate aircraft landings in poor weather conditions for which instrument flight rules (IFR) go into effect. This is in contrast to the less conservative approach, which assumes visual meteorological conditions (VMC) and uses visual flight rules (VFR) ("Flight Category Definitions"). Furthermore, the ERRA landing system ground equipment is chosen to accommodate a precision approach, which provides both vertical and lateral guidance, as opposed to a non-precision approach, which only provides lateral guidance ("Aircraft Equipment").

Flight category definitions:

Category	Ceiling		Visibility
Low Instrument Flight Rules LIFR* (magenta sky symbol)	below 500 feet AGL	and/or	less than 1 mile
Instrument Flight Rules IFR (red sky symbol)	500 to below 1,000 feet AGL	and/or	1 mile to less than 3 miles
Marginal Visual Flight Rules MVFR (blue sky symbol)	1,000 to 3,000 feet AGL	and/or	3 to 5 miles
Visual Flight Rules VFR+ (green sky symbol)	greater than 3,000 feet AGL	and	greater than 5 miles

*By definition, IFR is ceiling less than 1,000 feet AGL **and/or** visibility less than 3 miles while LIFR is a sub-category of IFR.
+By definition, VFR is ceiling greater than or equal to 3,000 feet AGL and visibility greater than or equal to 5 miles while MVFR is a sub-category of VFR.

Figure 5: Federal Aviation Administration Flight Category Definitions

Figure 5 shows that Instrument Flight Rules are utilized in conditions that have poorer visibility than the conditions in which VFR are utilized ("Flight Category Definitions"). This is a more conservative approach that ensures the safety of the ERRA and would allow aircraft to land at night as well as during the day.

ERRA Technology

This section is divided into two categories. The first addresses the technological equipment that an ERRA requires to aid in navigation and surveillance of aircraft and to communicate with pilots. The second addresses the technological equipment required to operate an ERRA and ensure effective ground-to-ground communication both within the ERRA and between the ERRA and WHO country offices and regional air traffic controllers.

1 | Navigation, Surveillance, and Communication with Aircraft

Several options exist to provide a precision approach landing, including, but not limited to, instrument landing systems (ILS), transponder landing systems (TLS), and satellite-based augmentation systems (SBAS) coupled with global positioning systems (GPS). In contrast to an ILS, which operates with a ground-based radio transmitter in conjunction with an aircraft receiver tuned to the ILS frequency, a TLS operates by utilizing the aircraft's transponder and various ground-based sensors to achieve transponder multilateration. Once the TLS has calculated the position of the aircraft, it broadcasts this information to the aircraft as localizer and glide slope signals ("TLS Transponder Landing System"). While the ILS is the most commonly used navigation equipment to assist in landings in IMC conditions, this system requires several ground-based components, including a very high frequency (VHF) localizer transmitter, ultra high frequency (UHF) glide slope transmitter, marker beacons, and approach lighting systems, that are not suitable for challenging terrain nor practical to install quickly at an ERRA ("Instrument Landing System"). Therefore, a TLS is preferable to an ILS in an ERRA context.

In contrast to an ILS or a TLS, a SBAS requires no ground-based equipment at the airport, which is a significant advantage when considering the rapid response goal of an ERRA. Certain regions of the world are provided a SBAS through a network of ground-based reference stations that collect satellite signal data and send it to ground-based master stations. The master stations are then able to analyze this data and correct it for errors, sending corrected signals to Geostationary Earth Orbit (GEO) satellites which then transmit the corrected signal to the SBAS receiver located in the aircraft. The aircraft must be equipped with the proper avionics, namely the Universal Avionics SBAS-Flight Management System. In this way, a SBAS is able to improve the accuracy of GPS so that the system may meet standards for an ILS approach ("Operating in SBAS Airspace"). For example, the North American SBAS, the Wide Area Augmentation System (WAAS), can provide an aircraft with its position to within 0.01 NM ("WAAS/SBAS-FMS Family").

However, a SBAS has a major disadvantage in the context of an ERRA because satellite-based augmentation systems currently do not provide coverage in every region of the world. Current SBAS coverage is shown in Figure 6 below. As stated previously in this report, the developing world, of which the majority is not covered by a SBAS, is more likely to face a world health emergency and is generally less equipped with adequate infrastructure to respond. As a result, the ERRA will most likely be located in a region that is not covered by a SBAS. Therefore, a TLS will be pursued as the primary recommendation for the ERRA.

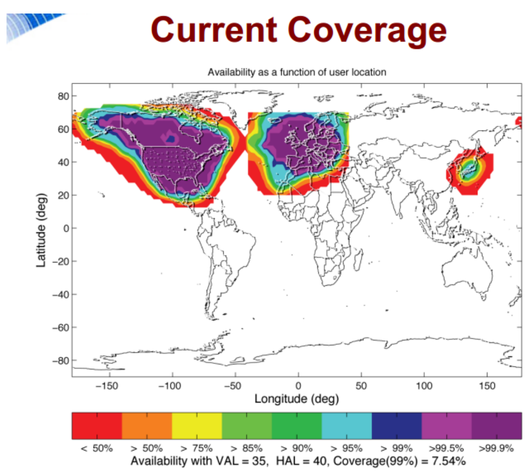


Figure 6: Coverage of SBAS [10]

A TLS has several benefits ("TLS Transponder Landing System"). First, it is both a precision landing system and a terminal area surveillance system in one piece of equipment. It meets ICAO standards for ILS, secondary surveillance, and precision approach radar (PAR). Second, a TLS can be utilized at airports where land and terrain constraints would otherwise prohibit the use of an ILS. For example, a TLS can be used at airports with short runways, runways that end at a body of water, and on sloping terrain. In addition, a TLS can be placed to the side of a runway or helipad, which is especially helpful for the seaplane landing as it would not be feasible to place an ILS over a body of water. Third, aircraft that are compatible with an ILS approach will also be compatible with a TLS approach. Aircraft must simply be equipped with an ILS localizer and glide slope receiver as well as a Mode 3/A or Mode S transponder. Fourth, the supplier of the TLS, Advanced Navigation & Positioning Corporation (ANPC), provides a transportable TLS (TTLS) that can be set up in less than 6 hours. The TTLS is transportable by trailer or by helicopter in transit cases that contain its power, equipment, and infrastructure. Fifth, it can operate in extreme weather conditions: between -50°C to 70°C, up to 160 km/h of wind, and relative humidity of up to 100%. Lastly, the TLS manufactured by ANPC is widely used by reputable organizations such as the Brazilian Air Force, the US Marine Corps, and the Royal Australian Air Force. ANPC currently has a contract with the US Air Force to continue developing the technology (Jenny Beechener), so we can expect the TLS to continuously improve.

Regarding a communication system between the operations team's air traffic controllers and pilots, very high frequency (VHF) radio can be utilized for air-ground communications according to the Federal Aviation Administration's (FAA) standards ("En Route Procedures"). Controller pilot data link communication systems (CPDLC) are also available as a supplement to voice communications, enabling pilots and air traffic controllers to communicate via readable messages on a datalink channel. However, voice communications via radio must remain the primary mode of communication according to the FAA. The FAA states that a CPDLC can increase an airport's operational capacity as well as decrease communication errors, which in turn can improve safety. While increasing operational capacity is not necessary in the ERRA context due to the low expected air traffic volume, if the aircraft servicing the ERRA are equipped with CPDLC avionics, then the air traffic controllers should utilize the feature to supplement voice communications. However, CPDLC may only supplement voice communications, and cannot replace them all together.

2 I Airport Management Technology

A ground communication system must be implemented to facilitate internal and external communications. Internally, the ERRA operations staff requires a method to communicate with other staff members located in different facilities of the ERRA. Externally, the ERRA operations team must remain in contact with both WHO country offices and the regional flight traffic management control center of the airspace in which the ERRA is located.

According to a study done on engineering and maintenance services for small hospitals in developing countries, where an ERRA will most likely be located, there are a few options for internal communication systems. These include two-way radios, pagers, and intercom systems (J.C. Mehta). A combination of these systems will be useful in an ERRA context. Handheld two-way radios or pagers will be useful in reaching staff that move about frequently within an ERRA and will not always be in hearing distance of a radio base station or intercom loudspeaker. Intercoms will be useful to the operations team, headquartered in the operations control tent, to broadcast information to the whole ERRA at one time. This would work by placing an intercom master station in the operations control tent and up to fifteen intercom substations at strategic locations throughout an ERRA. The master station can relay messages to up to six substations at once. These substations can then respond individually to the master station (J.C. Mehta). In this way, the operations team can be better equipped to efficiently transmit urgent information in the event of an emergency.

External communication methods will vary based on the site location. Some regions may not have adequate cell coverage or connectivity to high-speed internet. As a safety net, we propose utilizing a combination of long-distance radio and satellite-based internet. The Ground Control Global Satellite Communications Company utilizes the technology shown in figure 7 below to provide internet access to any region in the world. According to the company, it can provide high-speed internet connectivity of up to 5Mbps for download and 2 Mbps for uploads. The company provides a variety of products for satellite internet connectivity that are portable, do not require trained personnel to set up, are operable in extreme weather conditions, and provide a local hotspot for both internet and phone (“How Does Satellite Internet Work?”).

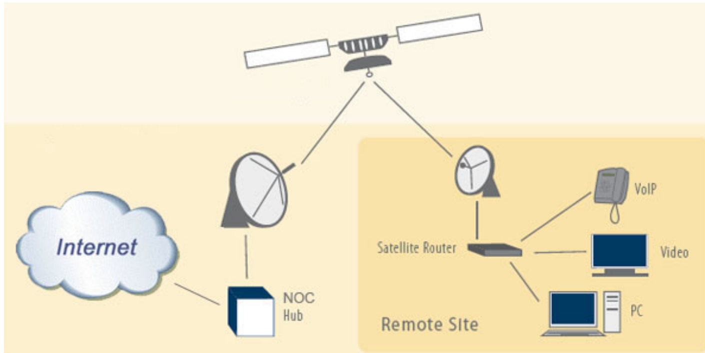


Figure 7: Satellite-Based Internet Technology

Figure 7 shows how satellite-based technology can connect a remote site to the internet ("How Does Satellite Internet Work?"). Data is transmitted from a small ground-based satellite at the remote site to another ground-based satellite via geosynchronous satellites. The key is that the second ground-based satellite at the Network Operations Center is connected to the internet.

The remaining technological equipment required for an ERRA includes, but is not limited to: a generator and proper power cables to power the ERRA; computers, a scanner, ethernet cables, radios, satellite dish from the Ground Control Satellite Communications company, satellite-based phones, and intercom stations for communications; security cameras and handheld metal detectors for security threat mitigation; and a lighting system to meet ICAO standards. Other needs, such as temperature regulation systems in extreme weather conditions, may arise in response to specific site conditions and should be dealt with accordingly.

Phases of Implementation

The lifetime of the ERRA is divided into four phases as follows:

1. Site and Design Selection
2. Assembly
3. Operations
4. Disassembly

Site Selection

It is the responsibility of the operations team staffed by WHO to select an appropriate site for the ERRA in collaboration with the local government of the population affected by the epidemic.

Several criteria of the site selection process are difficult to quantify but are, nevertheless, important. Such criteria include the level of cooperation of the local government and the willingness of unhealthy people to leave their homes to seek medical attention. These factors should be considered by the operations team following the use of the decision support algorithm proposed below. The following factors are possible to quantify but are not included in the decision support tool: the availability of local construction materials; the existence, accessibility, and capacity of local hospitals to effectively treat patients; and the level of contagiousness of the epidemic (Rodrigue, Luke, and Osterholm). (If the epidemic is highly contagious, affected people would expose healthy people to the disease when using existing transportation modes to access the local hospital.) These considerations are not included in the decision support algorithm for the sake of simplicity. However, the operations team should take these factors into account following their use of the decision support algorithm.

The decision support algorithm proposed below is adapted from Dr. Scott Moura's "WIFI for All: Tower Location Optimization Via Nonlinear Programming". The problem is approached by formulating an objective function and constraints, downloading density population data, and utilizing nonlinear programming techniques (Moura). The location is constrained to a rectangular section scaled to $(x, y) \in [0,1] \times [0,1]$. Given a population density function $\rho(x, y)$ and a maximum coverage radius of R_{Max}, the objective function maximizes the total population reached.

Maximize

$$f(x_0, y_0, R) = \int_0^{2\pi} \int_0^R \rho(x_0 + rcos\theta\,, y_0 + rsin\theta)\; r\; dr\; d\theta$$

where (x_0, y_0) denotes the optimum tower location.

Subject to:

$$x_0 - R \geq 0$$
$$x_0 + R \leq 1$$
$$y_0 - R \geq 0$$
$$y_0 + R \leq 1$$
$$R \leq R_{Max}$$

$$R \geq 0$$

The first four constraints constrain the coverage area to exist within the rectangular section $[0,1] \times [0,1]$, the fifth constraint ensures that the radius of coverage does not exceed the maximum, and the sixth constraint is a non-negativity constraint. In the case that a population density function is not readily available, a solution can be obtained by interpolating and numerically integrating population density data.

The case of selecting a site for an ERRA is analogous to the Wi-Fi tower placement problem. Rather than having population density data for the entire population, the decision support algorithm would require population density data for people affected by the epidemic. The maximum radius of Wi-Fi coverage, R_{Max}, is analogous to the maximum distance that affected people would be willing and able to travel to reach the ERRA site. Assuming that the rectangular region is large enough, the ERRA can be considered a point location in comparison to the service region. If population density data for people affected by the epidemic is available within a large rectangular region, it can be scaled to $(x, y) \in [0,1] \times [0,1]$. Then, portions of the rectangular region can be made infeasible through additional constraints so that the rectangular region of feasibility does not include sites that are unsuitable for an ERRA such as bodies of water, villages, swamps, mountains, or protected land. Following this procedure, $(x, y) \in [0,1] \times [0,1] - [a_1, b_1] \times [c_1, d_1] - \cdots - [a_k, b_k] \times [c_k, d_k]$ where a_k, b_k bound the x coordinates of the k^{th} infeasible region and c_k, d_k bound the y coordinates of the k^{th} infeasible region.

Following the results of the decision support algorithm, the operations team should weigh the previously mentioned factors not accounted for in the algorithm into their decision. In addition, they must check that the dimensions of the ERRA designs (listed in the "Design" section) are compatible with the available proposed site, as we previously assumed the ERRA to be a point. This phase of the site selection process will inform the design selection process.

Design Selection

ERRA Design One is designed to accommodate a civil tiltrotor while Design Two is designed to accommodate both a civil tiltrotor and a seaplane. Design Two is the default recommended design. However, if a body of water suitable for a seaplane landing is not available, then Design One should be selected. If the selected site is in close proximity to a body of water suitable for a seaplane landing, then Design Two should be chosen.

Assembly

The response time of an ERRA is defined as the amount of time required to transport the required materials to the selected site and to construct and assemble all components of an ERRA. The response time does not include navigating the bureaucratic steps of WHO and the affected region's government. The response time will vary based on the site selected. Site selection will affect the response time for several reasons. First, the availability of local materials and equipment will reduce the response time by decreasing the time required for supplies to reach the ERRA (Hababou). Second, the conditions at the site will determine whether or not compacted dirt will be sufficient for the vertical take-off and landing (VTOL) surface. In rainy weather conditions, the VTOL would turn to mud, so rapid-setting concrete may need to be utilized instead. Third, extreme weather conditions may decrease the productivity of the operations team in the assembly phase. Because there are so many variables in determining response time, this aspect of the ERRA project requires further research once site conditions have been specified. However, a best-case scenario is roughly approximated as follows:

Step 1 | Transportation of Materials to Site

3-4 days

Materials, equipment, and staff are transported to the site via trucks and/or helicopters. Temporary tents are set up.

Step 2 | Pre-assembly

1-2 days

Any disturbances on the ground, such as rocks, are removed. Future facility locations are measured and marked on the ground using spray paint or flags. Cable network pathways for ethernet and power are identified. Light, security camera, and intercom station locations are identified and marked. Pathways for walking are designated.

Step 3 | Assembly and Construction

4-5 days

Long-lasting tents are erected. A ground-based satellite dish for internet is connected to ethernet cables, connecting all computers, security cameras, intercom stations, and lighting systems. Hazmat equipment is set up in the quarantine and isolation terminal. The TLS is set up and placed appropriately to the side of the tentative VTOL location and/or the body of water on which the seaplane will land. Power cables connect all electronics to the generator. The VTOL is created with a dirt compacting machine. Fencing is placed around the perimeter of the site.

Step 4 | Testing and Preparation

2-3 days

All supplies are properly stowed in appropriate storage facility. Locally-sourced construction staff depart and remaining operations team rests and trains for operations by doing test run-throughs. Equipment is given a final testing and inspected for proper set-up. An inventory of essential supplies is taken. The operations team awaits instructions from WHO country offices and the GEMT-R.

Operations

From the operations control tent, the team can:

1. Monitor the security cameras to maintain awareness of all site activities.
2. Adjust the lighting of the ERRA based on needs.
3. Maintain a database of health records of all ingoing and outgoing personnel.
4. Maintain a database of supplies.
5. Manage internal ground-based communications via radio and intercom, and external ground-based communications via Internet and long-distance radio.
6. Act as air traffic controllers for approaching and departing aircraft utilizing radio, secondary surveillance radar (SSR), and precision approach radar (PAR) enabled by the TLS. According to the FAA, additional precautionary procedures must be implemented when operating at an airport without an air traffic control tower. It is imperative that all aircraft radios operate at a common radio frequency so that pilots can make self-announce broadcasts to communicate with aircraft in the vicinity ("Air Traffic Control").

Disassembly

This is the reverse of the process outlined in the assembly phase. The timing of this phase is not as critical as that of the assembly phase because the ERRA is no longer being depended on to mitigate an international health crisis.

Health Safety

In the event of an epidemic, an Emergency Rapid Response Airport (ERRA) must be capable of transporting people and supplies in and out of the affected area as urgently as possible, but most importantly must not exacerbate the epidemic. Transportation is a dangerous, yet effective means for the spread of infectious disease (Rodrigue, Thomas, and Osterholm). Even though an ERRA is designed to be minimalist, it is imperative that all necessary safety precautions to prevent the spread of disease are taken. The World Health Organization (WHO) characterized the importance of transportation in sustaining global public health in their 2007 Annual Report: "today's highly mobile, interdependent and interconnected world provides myriad opportunities for the rapid spread of infectious diseases…infectious diseases are now spreading geographically much faster than at any time in history" (Topinka). Airports are undoubtedly crucial choke points in transportation that can be strategic locations for controlling epidemics. During the course of our research, we examined current practices and internationally accepted standards and used them as guidelines to develop key aspects our ERRA would need to maintain public health, while still being assembled quickly in limited resource areas.

Background on Isolation, Quarantine, and Infectious Disease

The words "isolation" and "quarantine" are oftentimes mistakenly used interchangeably, but in epidemiology and public health studies, the differences between them are crucial. Isolation refers to separating an already confirmed ill patient from the general public to prevent the spread of their disease, while quarantine is the segregation of people who are suspected to have come in contact with a communicable illness (Topinka). While there are defined regulations on best practices to isolate people who are already confirmed ill, there is some controversy on when and how to *quarantine* people ethically who are thought to only possibly be contagious. In an Emergency Rapid Response Airport, it is vital that the ill are properly isolated and the possibly contagious are properly quarantined in an ethical, but feasible fashion considering limited resources.

Additionally, during our research, we found that it necessary that the Emergency Rapid Response Airport is tailored to the type of infectious disease and its level of contagiousness. In the *2007 Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in*

Healthcare Settings, the Center for Disease Control (CDC) classifies infectious disease into three categories based on their form of transmission: contact transmission, droplet transmission, and airborne transmission (United States of America). Contact transmission is classified into two subcategories, direct contact and indirect contact transmission, and occurs when "microorganisms are transferred from one infected person to another person" with or without a "contaminated intermediate object or person" (United States of America). Droplet transmission disease can be contracted through "respiratory droplets carrying infectious pathogens" typically generated when a person coughs, sneezes, or talks. Airborne transmission, the most infective disease "occurs by disseminating of either airborne droplet nuclei or small particles in the respirable size range containing infectious agents that remain infective over time and distance" (United States of America). Below is a chart that displays different infectious diseases in each of the CDC classifications.

Table 1: CDC Classifications of Infectious Diseases

Contact Transmission	Droplet Transmission	Airborne Transmission
· Scabies · Herpes simplex virus · Measles · Mononucleosis	· Whooping cough · Tuberculosis · Bacterial meningitis · Strep throat	· Meningococcal disease · Severe Acute Respiratory syndrome (SARS)

Health Safety Authority and Leadership Organization

International airports are centers for information and key to maintaining public health. If utilized strategically, airports can mitigate the spread of communicable disease through detailed planning and deliberate delegation of responsibilities. By creating a specific plan for the implementation of an ERRA, we hope to clarify loosely defined roles for controlling disease at transportation hubs. One of the major public health problems facing developed countries is unclear organization; which authorities are responsible to take what actions in the onset of an infectious disease? In addition the tangle between public health agencies, transportation agencies, local authorities, federal authorities and international regulations make delegating responsibilities exceedingly complex.

Even in the United States, which has a developed public health emergency plan, understanding which parties holds what responsibilities is not always so clear. The CDC, a federal agency, oversees quarantine and has the authority to assist local municipalities in quarantining suspected infected individuals. However, the "federal quarantine regulations must not conflict with state or municipal authorities" (Topinka). Additionally, the federal level can enforce disease regulations when local municipal statutes are insufficient. This multi-tier enforcement strategy is inefficient, overly complex, and oftentimes redundant. The current structure leaves too much room for error, when error has exceedingly perilous consequences. To examine the importance of effective organization in the event of an epidemic, we studied two cases: the first, a series of oversights during the 2014 Ebola outbreak, which left one person dead and others critically ill; and the other, an in-depth study of Chicago O'Hare International Airport's quarantine plan.

Thomas Duncan: The Blame Game

On September 19, 2014, Thomas Duncan, the first person diagnosed with Ebola in the United States, entered the U.S. through Dallas Fort Worth International Airport from Liberia (Onishi and Santora). The New York Times reported that when Duncan flew out of Roberts International Airport in Monrovia, the Liberian capital, he responded on a questionnaire that he did not have contact with anyone with Ebola, so he was not sent to secondary screening (Onishi and Santora). Duncan was not further screened or questioned when he entered the United States. It was later found that he did in fact have contact with a woman from his community who died of Ebola.

A few days after his arrival, Duncan admitted himself to the Texas Health Presbyterian Hospital emergency room exhibiting flu-like symptoms, but was released several hours later. It was not until four days later that he readmitted himself to the hospital and was diagnosed with the deadly Ebola hemorrhagic fever. Duncan was then treated by health care professionals who abided by CDC isolation guidelines. Nevertheless, unfortunately, Thomas Duncan died on October 8th, at age 42 from the deadly disease. Subsequently, two nurses became infected with Ebola, many became fearful that they too would become ill, and even more were dumbfounded by the relaxed health screenings at airports. Additionally, one of the infected nurses traveled to Cleveland by airplane before she was ill, but after she treated Duncan, which furthered sentiment about insufficient health screening at airports.

While it is unproductive to blame individuals for the lapses in the care of Thomas Duncan and the containment of his disease, it is imperative to identify ways to prevent a case like Duncan's from occurring again. It is clear that poor preparedness was a significant factor and the roles of transportation, public health, local, and federal authorities were not sufficiently defined. As we constructed the health and safety guidelines for an ERRA we ensured that recommended practices were clearly defined, because as seen in Duncan's case, a single lapse in the care of an affected person can have significant ramifications.

Chicago O'Hare International Airport: A Case Study

In "Yaw, Pitch, and Roll" Joseph B. Topinka also emphasizes the importance of defining who has authority over which operations as crucial to controlling the spread of infectious disease. In his report, he depicts the Chicago O'Hare International Airport quarantine plan. Most major aviation transportation hubs have a quarantine station, which is not a physical location, but "small groups of public health officials located at major United States airports" (Topinka). At O'Hare, the quarantine station is headed by an officer in charge, and has one quarantine medical officer, four quarantine public health officers, and two administrative assistants (Topinka). This group of eight individuals is tasked with stopping the spread of disease that would otherwise originate from one of the busiest aviation hubs in the country. Topinka then goes on to discuss how these eight individuals fit into the larger local, state, and federal disease control jurisdictions. All quarantine stations operate under the CDC. However, "at O'Hare International Airport, the state of Illinois and the city of Chicago have concurrent isolation and quarantine authority with the CDC" (Topinka). This definition has overlapping roles which leads to sluggish action and futile blaming.

Even though jurisdiction roles are not sufficiently clarified in the event of an epidemic, history shows the party in charge is typically dependent on the scope of the incident. In his report, Topinka raises many questions that are still unclear within the O'Hare quarantine plan: "For example, is it a federal event when a sick passenger arrives at O'Hare from another country 'until Customs and Border Protection stamps in the person, at which point it goes to the locals?' Is it 'a Federal event until the matter of isolation and quarantine is fully resolved?' Does it make a difference that current regulations are old and do not encompass the new travel realities?" (Topinka). There is much that is still unclear in the Chicago O'Hare quarantine plan. However, we used the questions the O'Hare system raises along with their authority hierarchy to help us better define a streamlined health safety authority structure at our Emergency Rapid Response Airport.

Health Safety Authority Organization Model at an ERRA

At an Emergency Rapid Response Airport, it is crucial that communication is swift and all operators are extremely clear on their responsibilities, especially those involved with health safety. Based on our research on current best practices, we recommend one Officer in Charge to be the authority on health safety at the facility. This officer would be in charge of ensuring that all ill passengers are properly isolated and determining if suspected affected travelers are quarantined according to internationally accepted guidelines. This individual would make all decisions regarding mitigating the spread of infectious disease, and would operate under the auspices of the World Health Organization (WHO). In addition, we recommend a minimum of two medical assistants, who would tend to sick passengers, however the number of medical assistants would be limited by the availability of properly trained health care workers. More medical assistants may be necessary depending on both the intended capacity of the ERRA and the severity of the illness of concern. Below is an organization chart which depicts the authority structure we recommend to help alleviate the spread of disease at an ERRA.

We expect that in certain situations, there will be controversy over who has control over how to treat the affected passengers at the ERRA. Figure 8 depicts the health safety authority hierarchy we recommend to streamline emergency response and address any controversy.

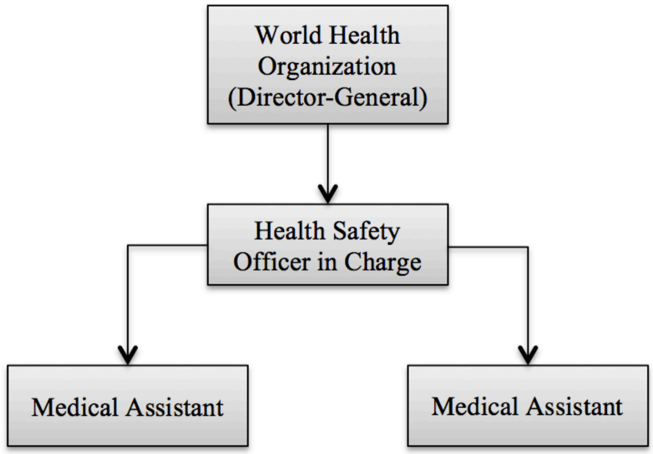


Figure 8: Health Safety Authority Organization

Health Safety Measures

While efficacious organization of authority will aid in the proper treatment of ill passengers and the safe transport of people and supplies, there are certain necessary measures that must be taken so that disease is not spread. Appropriate quarantine and isolation, personal protective equipment, decontamination, and management of hazardous waste are necessary for an ERRA to aid affected regions in the face of an epidemic.

Affected Passenger Facilities

If an affected person is infected with any sort of communicable disease, the CDC recommends that patients be separated in different rooms. However, due to the minimal nature of Emergency Rapid Response Airports, this is likely not possible. Instead all confirmed affected passengers would be separated in an isolated terminal-like temporary structure as outlined in the Design section. This would allow adequate separation between healthy and ill passengers, while still allowing the ERRA to be set up as rapidly as possible. Additionally, we recommend a similar quarantine terminal for those who are suspected of exposure to the illness of concern. Furthermore, there would be a medical tent for medical assistants, supplies, and decontamination. These three temporary structures, the isolated terminal, the quarantine terminal, and the medical tent, make up the affected passenger facilities at an Emergency Rapid Response Airport.

Personal Protective Equipment

In order to assess the necessary level of personal protective equipment and caution required to limit the spread of disease, we examined established international standards and categorizations. Personal Protective Equipment (PPE) is separated into four categories, Level A through D. Level A as the most protective against skin, respiratory, and eye contaminants, and Level D as the least protective, only guarding against "nuisance contamination" (Occupational Safety and Health Administration). Below is a summary of the different levels of PPE and what equipment is mandated for each level as outlined in the internationally accepted Occupational Safety and Health Standards (OSHA) under the US Department of Labor (Occupational Safety and Health Administration No. 1910.120 App B, § H-H)).

Level A

To be selected when the greatest level of skin, respiratory, and eye protection is required

Figure 9: Level A Protective Suit

1. Positive pressure, full face-piece self-contained breathing apparatus (SCBA), or positive pressure supplied air respirator with escape SCBA, approved by the National Institute for Occupational Safety and Health (NIOSH)
2. Totally-encapsulating chemical-protective suit
3. Coveralls*

4. Long underwear*
5. Gloves, outer, chemical-resistant
6. Gloves, inner, chemical-resistant
7. Boots, chemical-resistant, steel toe and shank.
8. Hard hat (under suit)*
9. Disposable protective suit, gloves and boots (depending on suit construction, may be worn over totally-encapsulating suit)

Level B

The highest level of respiratory protection is necessary but a lesser level of skin protection is needed.

Figure 10: Level B Protective Suit

1. Positive pressure, full-facepiece self-contained breathing apparatus (SCBA), or positive pressure supplied air respirator with escape SCBA (NIOSH approved)
2. Hooded chemical-resistant clothing (overalls and long-sleeved jacket; coveralls; one or two-piece chemical-splash suit; disposable chemical-resistant overalls)
3. Coveralls*
4. Gloves, outer, chemical-resistant

5. Gloves, inner, chemical-resistant

6. Boots, outer, chemical-resistant steel toe and shank

7. Boot-covers, outer, chemical-resistant (disposable)*

8. Hard hat*

9. Face shield*

Level C

The concentration(s) and type(s) of airborne substance(s) are known and the criteria for using air purifying respirators are met.

Figure 11: Level C Protective Suit

1. Full-face or half-mask, air purifying respirators (NIOSH approved)

2. Hooded chemical-resistant clothing (overalls; two-piece chemical-splash suit; disposable chemical-resistant overalls)

3. Coveralls*

4. Gloves, outer, chemical-resistant

5. Gloves, inner, chemical-resistant

6. Boots (outer), chemical-resistant steel toe and shank*

7. Boot-covers, outer, chemical-resistant (disposable)*

8. Hard hat*

9. Escape mask*

10. Face shield*

Level D

A work uniform affording minimal protection: used for nuisance contamination only.

Figure 12: Level D Protection

1. Coveralls

2. Gloves*

3. Boots/shoes, chemical-resistant steel toe and shank

4. Boots, outer, chemical-resistant (disposable)*

5. Safety glasses or chemical splash goggles*

6. Hard hat*

7. Escape mask*

8. Face shield*

* *optional (circumstance dependent)*

(Occupational Safety and Health Administration, No. 1910.120 App B, § H-H)

Hazmat requirements at the affected passenger facilities at an ERRA are determined by the level of contagiousness of the disease at hand. Understanding the different PPE guidelines is crucial to understanding the necessary health precautions at an ERRA. The three CDC categories of infectious disease as outlined at the beginning of this section, contact transmission, droplet transmission, and airborne transmission, would all have different best practices further detailed in the chart below.

Table 2: PPE Recommendations

Disease Type	Contact Transmission	Droplet Transmission	Airborne Transmission
Recommended Type of PPE	Level D or C	Level C or B	Level B

While this table can be used to determine proper PPE in most cases, the Health Safety Officer-in-Charge would have final say in proper health procedures and should follow the most widely accepted procedures pertaining to the epidemic of concern.

Decontamination and Waste Management

It is extremely critical that all medical assistants and anyone who has had contact with affected passengers follow strict decontamination protocol. It is standard procedure for the World Health Organization to compile an Infection Prevention Control (IPC) Guide Summary for an epidemic or transmissible disease of question. The IPC outlines all acceptable procedures including proper medical care, hygiene, environmental cleaning, and proper post-mortem care. The IPC Guidance Summary is clear and brief for practical and efficient use. To characterize decontamination methods at an ERRA, we reviewed the IPC Guidance Summary for Ebola, which was compiled in August 2014. An example of a chart that summarizes all acceptable procedures for handling patients with suspected or confirmed Floviros haemorrhagic fever (Ebola) can be found in Appendix A-5. All procedures at an Emergency Rapid Response Airport would strictly follow WHO guidelines outlined in a similar chart for the disease at hand.

Figure 13: Decontamination Example 1

The decontamination protocol that has the most significant effect on the design of an ERRA is the mandate that once health personnel leave the affected area of the airport, they must be sprayed with hospital disinfectant (e.g. a 0.5% chlorine solution or a solution containing 1000 ppm available free chlorine) (World Health Organization, IPC). An ERRA must have a decontamination annex, located in the medical tent, to serve health care professionals treating both isolated and quarantined individuals. These annexes must be completely sealed off from the outside environment and must be waterproof (see Figure 13). As seen in Figure 13, all personnel assisting in the decontamination process must also wear PPE. Temporary decontamination rooms are used by WHO and have been very effective in containing the spread of the most recent Ebola outbreak in West Africa (World Health Organization, IPC). Figure 14 shows a readily available temporary decontamination room called "D-Con Disposable Shower Enclosures" made by Grayling ("Grayling Industries"). While it is preferable that materials at an ERRA are locally available to assist in the rapid construction of the airport, it is likely that certain health safety materials are not available locally. However, according to the World Health Organization's No-Regrets policy, the Organization is willing to do what it can to mitigate as many dangers as possible. For this reason, we believe it is acceptable to import certain health related materials to the site of the Emergency Rapid Response Airport.

Figure 14: Decontamination Example 2

Additionally, it is critical that all infected waste is properly cared for. While it is the preferred and safest option to throw away most of the PPE, certain items would be thoroughly cleaned and decontaminated for reuse. Items to be thrown away should be bagged and clearly labeled as outlined in the WHO IPC Guide Summary. ("Grayling Industries") Possible hazardous material storage includes metal or plastic hazardous waste storage bins similar to the ones shown in Figure 15. As for contaminated human waste and other biohazardous waste, the internationally accepted standard is to label very clearly all items and store them in a secure location until they can be safely disposed of.

Figure 15: Biohazardous Waste

While it is desirable that an Emergency Rapid Response Airport is set up rapidly and is run efficiently, it is most important that the epidemic is not exacerbated. Transportation is a dangerous means for the spread of infectious disease, but with the medical organizational structure and health safety measures outlined in this report we believe an ERRA can be constructed quickly while maintaining health safety for passengers, operators, and medical staff, as well as preventing the international spread of the disease.

Security and Risk Mitigation

Airports are vulnerable locations and are prone to many different types of security risks. We expect Emergency Rapid Response Airports to be especially vulnerable to security risks because of the unstable nature of the affected region and high-stakes nature of transportation in the face of an epidemic. For this reason, even though an ERRA should be assembled as quickly as possible, it is also necessary that all security precautions are considered and all obligatory measures are taken. We analyzed the necessary security steps in a similar manner to that in which we studied health safety. We first considered current best practices in more established airports and transportation facilities and then abandoned redundant, less critical measures to preserve the swift construction of an ERRA while still maintaining security. After much research, we identified two main subdivisions of ERRA security:

1. The organization of security authority and leadership, and
2. the measures and practices that make an airport secure.

These two different aspects of security are analyzed below.

Security Authority Organization

Similar to the health safety authority organization, security at an Emergency Rapid Response Airport must have defined leadership roles. We designed the security leadership roles to be as minimal as possible to preserve the efficiency and rapidness of an ERRA. The following is a flowchart modeled off the ERRA health safety authority roles which defines who is in charge of what roles relating to security and risk mitigation.

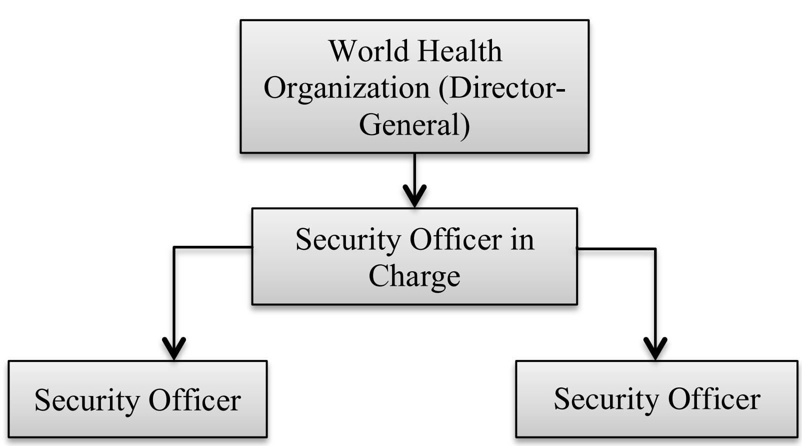


Figure 16: Security Authority Organization

In consistency with the rest of WHO organizational structure, the Director-General would have the final say in security decisions and the responsibility of coordinating with other international authorities to determine best practices. The Security Officer in Charge would be the regional authority on matters of security risk and safety and would communicate directly with and organize the duties of security agents. Lastly, security agents would be vetted by WHO and other local and international authorities. It is possible they would be from military, local law enforcement, private security, or international aid depending on the stability and resources of the ERRA location.

Security Measures

While it is crucial that appropriate duties of security personnel are defined, it is also necessary that appropriate resources and security equipment is present onsite at an Emergency Rapid Response Airport. The two main minimum-security requirements for an Emergency Rapid Response Airport are perimeter fencing and a closed circuit television system. These relatively low cost, but effective measures are essential at such a high-risk.

The recommended perimeter fencing to be used is based on the most available materials. From studying widely available materials in underdeveloped regions, we found that chain link fencing barbed wire, masonry bricks, and concrete cinder blocks (Hababou). are a few typically available materials in underdeveloped regions that would be appropriate to block off an ERRA from its surroundings. The only criterions are that the fence deters and prevents unauthorized individuals from entering ERRA premises and that it can be assembled quickly.

Figure 17: Example Camera

Again, because of the high-stakes nature of an Emergency Rapid Response Airport, it is imperative that there is a closed circuit television (CCTV) system on-site. One CCTV system we recommend is the IVC PTZ-HD30-6 because it requires only a power source and Ethernet connection to run. If the Ethernet cable connections are not reliable, we recommend any other available and plausible surveillance system, and in the most limited scenario, a visual observation method.

Even though an Emergency Rapid Response Airport is quite different from a commercial airport, it must maintain some level of security. With the authority structure and measures we have defined, we believe that an ERRA could be adequately protected from likely security risks. Furthermore, security risk is exceptionally dependent on the location of the airport, and additional measures should be taken if deemed necessary.

Design

Facilities

1 I Check-in Area

The first part of the Emergency Rapid Response Airport (ERRA) a passenger will interact with is the Check-in Area. This area, which will be located within a tent, will be in charge of three primary tests: checking the flight eligibility of the passenger, security screening, screening non-passengers through a security check-point, and providing the appropriate personal protective equipment (PPE). The Check-In Area will be staffed with members of the operations team capable of completing check-ups and providing security.

Eligibility of the affected or exposed persons to be transferred through the ERRA should be determined through two documents and one medical check-up. The first is a document produced by the WHO Country Office or by other competent intergovernmental organizations, which recommends the patient for immediate transfer to a hospital or country that can handle the disease. This document, which should be issued in moderation due to capacity constraints of the ERRA, will provide a barrier for patients who have not sought help locally to pursue medical care abroad. This limits the number of affected people leaving the affected area. The second document will include information pertaining to the Declaration of Health. This document will serve to keep track of the affected and exposed persons who have left through the ERRA and provide the pilot with the information necessary to fill out the Declaration of Health. The Declaration of Health is an amended version of WHO's 2005 International Health Regulation's document, "Model of Maritime Declaration of Health" and is found in Appendix A-6. It is the pilot's responsibility to ensure the form is filled out prior to take-off. Lastly, the individual will go through a procedural check-up performed by a doctor in the operations team. This procedure will define if the person is fit to fly and would benefit from the trip.

The second function of the Check-in Area is to ensure the airport does not reach capacity. Non-Passenger admittance should be kept to a minimum as they increase security risks, take up space, and promote the spread of the disease as they may be exposed to affected passengers or vice versa.

Finally, the Check-in Area is responsible for providing the appropriate PPE for affected and exposed individuals. Such equipment—which may range from medical masks to full suits—should be provided at the Check-in Area to reduce the possibility of exposure of the operations team and other personnel. To determine which type of PPE is required, please refer to the Health Safety Measures subsection of the Health Safety section.

2 I Operations Area

The primary function of the Operations Area should be to house air traffic control (ATC) and other members of the operations team. This area should be housed in a tent. The tent should directly face the vertistop to increase visual control of the airport. The generator should be located directly next to the Operations Area so as to be located near the majority of the electronic equipment, and further from the Terminal Area so as not to disturb passengers. For more information on the functions of the Operations Area, refer to the Operations and Logistics section.

3 I Terminal Area

The Terminal Area should be divided into three sections: two should be based on the type of individual it will be serving and one for the medical team. The first of the three terminal sections is the Quarantine Terminal. The Quarantine Terminal should be designated for all patients who are defined as exposed, yet not necessarily affected. While it would be dangerous to place people with different levels of exposure together for fear of further exposure, because individuals should have received appropriate PPE, there is no need to distinguish between levels of exposed individuals. The Isolation Terminal should be dedicated to known affected patients. The Isolation Terminal will make sure these individuals are not in direct contact with exposed individuals or the operations team directly. Both terminals should be located near the vertistop, adjacent to the Operations Area and on the opposing side of the generator.

The third section should house the medical team. A medical team should service the Terminal Area in case there are any emergencies or addressable discomforts. This medical area should have two components: a Medical Tent and a Decontamination Room. The Medical Tent will be directly next to the Terminal Area and will be used in extreme cases where the medical discomfort cannot be treated within the Quarantine Terminal or the Isolation Terminal without causing other individuals to panic or be further exposed. The Decontamination Room is next to the Medical Tent and will service both the Medical Tent and the entrance to the Terminals.

4 | Non-contaminated Contaminated Rest Area

The goal of the Non-contaminated Rest Area is to create a space where individuals working at the ERRA can convene during the day and rest overnight. People with access to the Non-contaminated Rest Area are members of the operations team and personnel who show no signs of the disease and have had little to no exposure. This includes pilots, air traffic controllers, on ground security, and doctors who have followed appropriate decontamination procedure throughout their interaction with the disease. The Non-contaminated Rest Area will provide an area to eat and rest—such as hammocks or mats—and may include a table for potential meetings of the operations team. The Rest Area will also have a provisional restroom, such as a portable toilet. This restroom should follow the standards outlined in the Decontamination and Waste Management subsection of the Health Safety section. The Non-contaminated Rest Area should be located next to the generator, as far away from the Terminal Area as possible. We recommend this layout to reduce the risk of exposure of non-contaminated people.

We also recommend that the area use energy efficiently to reduce the overall energy consumption of the airport. Cooking, for example, can be done with a machine with cogeneration, such as the BioLite. This would allow people to cook while charging important hand-held devices, such as cell phones or transceivers (BioLite CampStove). Another way to reduce energy consumption is to use a small-scale Stirling Engine that can run on any form of combustible waste.

5 | Storage

The ERRA needs to have a storage area to store fuel, food, and medical supplies. It should be located near the vertistop so the civil tiltrotor and the seaplane can be refueled easily. It should also be near the Non-contaminated Rest Area so that the operations team and personnel can access food. More importantly, it should be as far away from the Terminal Area as possible to reduce the potential of contamination.

The dimensions of the storage unit will be determined by the amount of required medical supplies, fuel requirements of serviced aircraft, the size of the operations team, and the capacity of the airport. The storage unit should be able to accommodate approximately a week of medical supplies and food, as well as a small section for hazardous waste. For more information on hazardous waste storage, please refer to the Decontamination and Handling of Waste subsection in the Health Safety section.

The storage unit should also provide space to accommodate enough fuel for two trips of the serviced aircraft. The aircraft selected for an ERRA have different fuel requirements. The Antilles Seaplane Model G-21G fuel tanks will occupy as much as 2,218 L, or approximately 22 m^3 (“Antilles Seaplanes Model G-21G”). The AugustaWestland AW609 civil tiltrotor’s standard fuel tank is 1,125 kg (“Tiltrotor”), which corresponds to approximately 1,390 L or 14 m^3 (“Fuel Weight Conversion Tables”). The storage unit should be able to contain fuel for at least two full tanks of either the AW609 or the AW609 and the Model G-21G, when the space is available.

6 | Vertistop

The Vertistop is the main vehicle takeoff and landing location for our airport. It will be located at the center of the airport so that it can be accessed from the Terminal, Operations, and Storage Areas. This will allow affected and exposed passengers to get to the civil tiltrotor without passing through other portions of the airport. Furthermore, it will allow for the fueling and unloading of delivered supplies without passing through the Terminal Area.

Specifications for the Vertistop are presented in the following subsection.

7 | Seaplane Dock

When the airport location is next to a sufficiently large river, a seaplane may also be used to move people and goods. In this case, a dock is necessary for people to board and for aid and food to be unloaded. Seeing as rivers are used as a medium for transportation in many countries, the dock should be designed to be removable so they do not interfere with larger passing boats. Furthermore, because we do not know how the local community will react to the airport as a whole, the less it intrudes upon their daily life, the fewer problems it will face. An easy and economical way to arrange the dock is to use either a matrix of flat buoys or wood laid out on top of buoys. The former option would allow the plane to dock on top of the flat buoys, making it ideal for boarding passengers (JetDock). The length of the dock should be sufficient to reach the main cabin without forcing the aircraft's wings to protrude over land.

Layout

All design concepts presented for the vertiport are taken from the *Federal Aviation Administration's Advisory Circular: Vertiport Design* to facilitate understanding and outline the necessary conditions for establishing a vertiport. While the FAA report does not regulate how vertiports should be constructed, it effectively offers guidance on how to do so.

We recommend that the design of the vertiport be made for instrument flight rules (IFR) instead of visual flight rules (VFR) to avoid any problems with weather. Since reliable data is not always given for the region in which the vertiport is being constructed, it is safer to plan for bad weather to ensure the ERRA can be used more frequently.

Similar to the vertiport, guidelines for the seaplane base are based on the Federal Aviation Administration's draft Advisory Circular: Seaplane Bases.

Airside

The ERRA must have the space for a square final approach and takeoff area (FATO) with 90 m sides. For every 300 m above sea level, this measurement should be increased by 15 m. The FATO area should be free of any obstacles and should not have a slope exceeding 1.5 percent. The FATO is defined with wit-ground edge markers separated 37 m around the FATO.

For IFR, the touchdown lift-off surface (TLOF) should be 45 m to 120 m on each side, site permitting. It should be designated with 40 cm wide white lines no more than 30 cm from the end of the TLOF and yellow L-861 omnidirectional lights spaced 9 m apart on the sides. The gradient of the TLOF should not exceed 1 percent. The FATO must be at least 90 m on each side because it must extend past the TLOF 22.5 m.

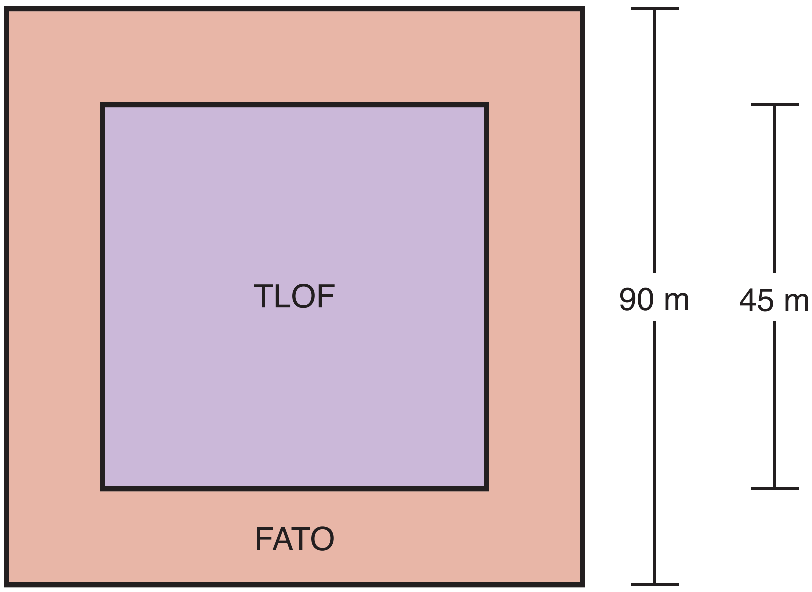


Figure 18: Simple FATO and TFOL configuration

Since the ERRA will only be servicing one aircraft at a time, there is no need to create taxiways or hover taxiways that lead to refueling and passenger boarding locations. Structures must be located at a safe distance from the FATO.

The FAA recommends that the vertistop be paved to avoid the spread of debris. Since the ERRA is made for emergency rapid response, the paved portions need to be reconsidered. Concrete typically takes at least 28 days to set, creating significant delays in the response time of the airport. One alternative is to use fast-setting Portland cement (Mehta). This would allow an acceptable strength to be achieved in as little as 0.5 hours. Another alternative is CTS Cements; their cement sets in 15 minutes and can be use for transit 1 hour after pouring ("Rapid Set Construction Cement"). If rapid-setting cement is not available in the region in which the ERRA is being constructed, compacted soil can also be used. Soil can be compacted with rollers, vibratory plates, pad compressors (Rogers), or livestock. To improve compaction—especially with livestock—moist soil is advised (Lamond). Paved surface or compacted soil should be designed to operate at 150% of the aircraft's landing weight. Independent of the nature of the surface of the FATO, a 7.5 to 11 m wide shoulder should be considered to decrease the debris coming off the FATO and into other areas of the ERRA.

Fueling should be performed through a hydrant system located near the Storage or through a small fuel truck. If a fuel truck is used, the truck should aim to minimize the time it is on the FATO area.

Airspace

While the FAA's Advisory Circular: Vertiport Design presents imaginary surface specifications for both VFR and IFR, we recommend building the airport based on IFR. Not only would this allow operations to happen during nighttime, we also do not know the climate of the epidemic region, so it is appropriate to plan for the worst-case scenario.

The approach surface connects to the primary surface located at the FATO and is 150 m wide. It extends for a horizontal distance of 1,500 m and becomes 600 m wide, which corresponds to a horizontal to vertical slope of 20:1. The transitional surface connects horizontally from the primary surface. It extends for 105 m at a slope of 4:1. The missed approach surface starts at the missed approach point before the FATO and is symmetrical in slope to the approach surface.

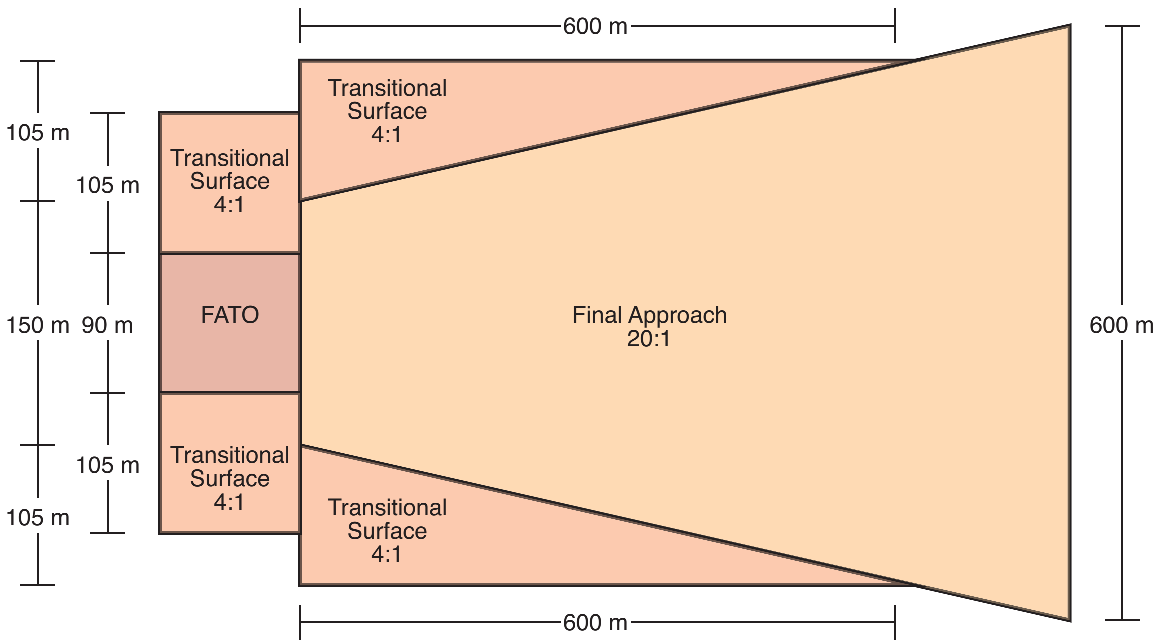


Figure 19: Top View of Imaginary Surfaces

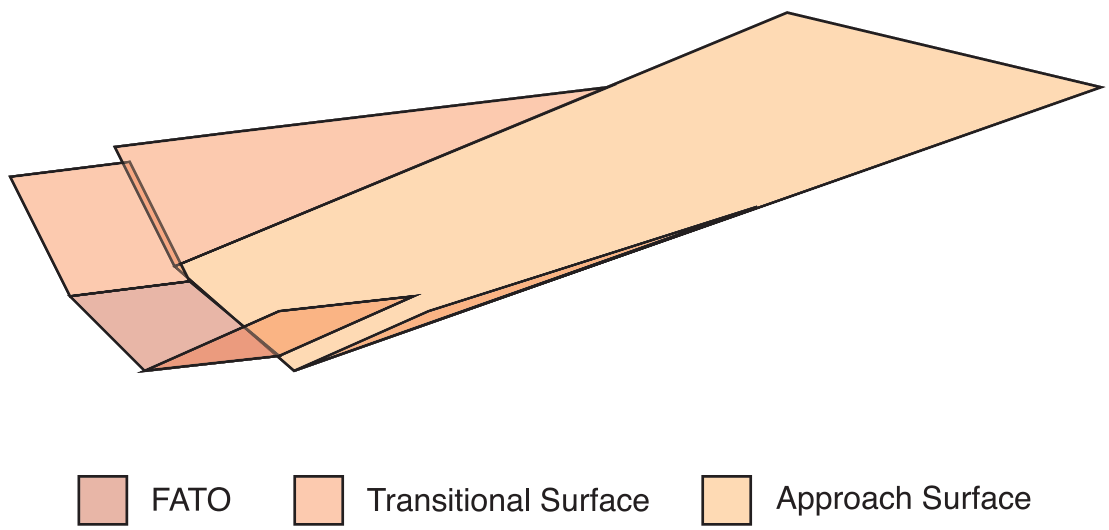


Figure 20: Three Dimensional Rendering of the Imaginary Surfaces

Landside

The Facilities subsection describes the facilities we recommend for the ERRA. Their relative positioning to each other aims to minimize the contact of non-exposed persons to those who are either affected or exposed by placing the Terminal Area and the Non-contaminated Rest Area far apart. It further seeks to eliminate the chance of contaminating food and medical supplies in the Storage. The facilities are placed around the vertistop based on their need to access it.

To determine the distance of buildings to the FATO, we looked at the imaginary surfaces. Assuming that the tents are at most 4 m tall, those located on the approach path or the missed approach path should be located at least 80 m away from the FATO. Tents located under the transitional surface should be 16 m away from the FATO.

Figures are not drawn to scale. For clarity, all of the figures feature the tents larger than they should be.

Overall Layout

The layout of the ERRA, while guided by the different FAA Advisory Circulars, is aimed at reducing the risk of further contamination. Both proposed designs keep the area that affected and exposed passengers will frequent—the Check-in Area and the Terminal Area—distant from medical and food supplies. Furthermore, the Non-contaminated Area is located far from the Terminal Area and Check-in Area so that members of the GEMT-R are at lower risks of exposure.

Waterside

When large bodies of water are available near the location of the ERRA, a seaplane dock can also be constructed to increase the capacity of the airport. The FAA's draft Advisory Circular: Seaplane provides a guideline for determining if a site is suitable for seaplanes and how to use available space.

According to Table 2-1 of the Advisory Circular, the minimum width and length of the river are based on the types of operations it will service. Our seaplane operations are classified as "limited float plane operations" and therefore require that the body of water have a minimum width of 200 m, a minimum length of 2,500 m, and a minimum depth of 1 m—although 1.8 m is highly recommended. In this case, the approach surface should have a slope of 20:1, like that for the tiltrotor. By establishing that both have the same approach surface angle allows us to use the approach path over body of water for the civil tiltrotor as well.

While the ERRA does not require taxi channels for the seaplanes because of the low traffic, it still needs to be anchored when not in use. The anchor location and length of anchor line must be such that there is at least a 15 m separation between the seaplane and any obstruction at all times.

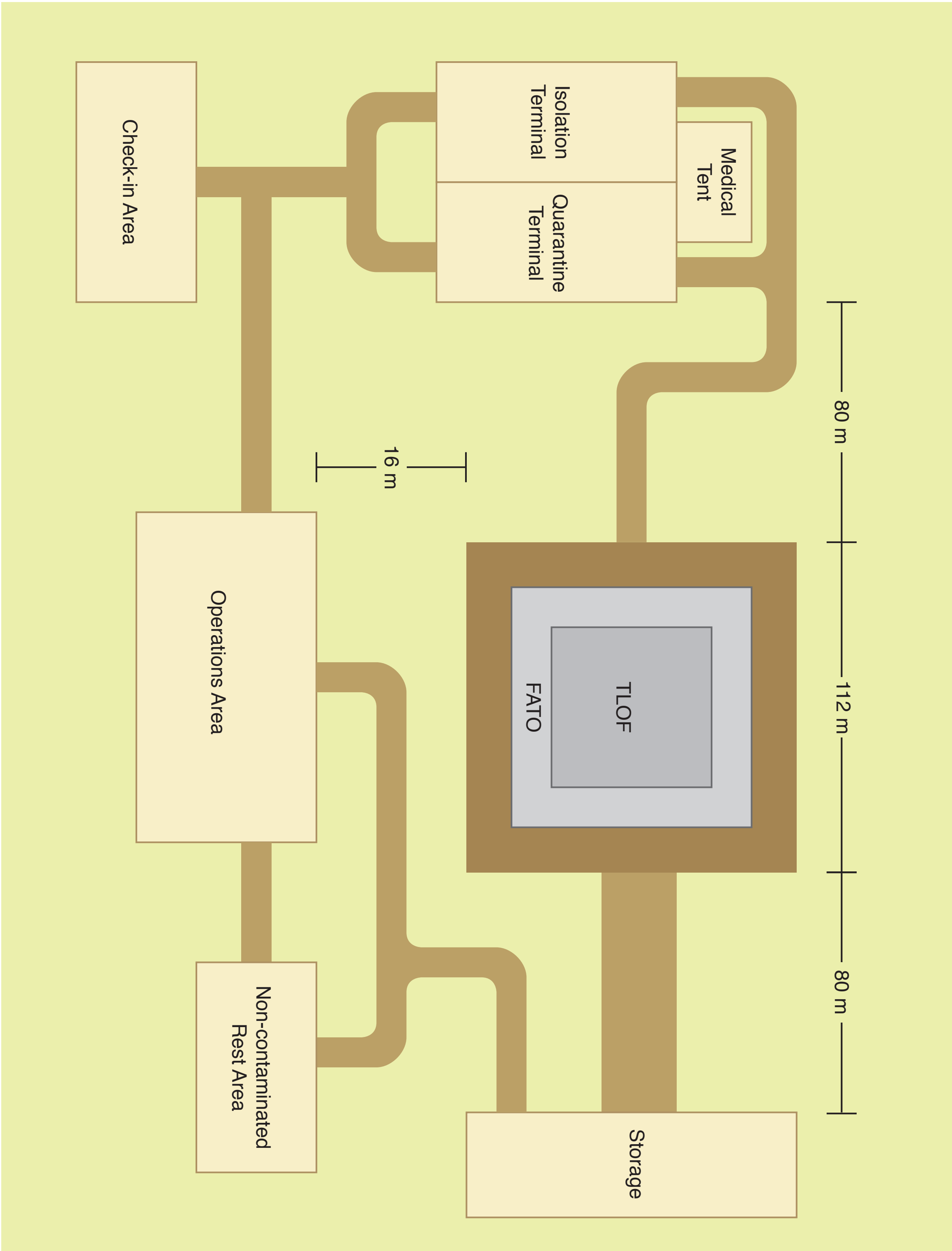


Figure 21: ERRA Proposed Layout with Minimum Separation Requirements

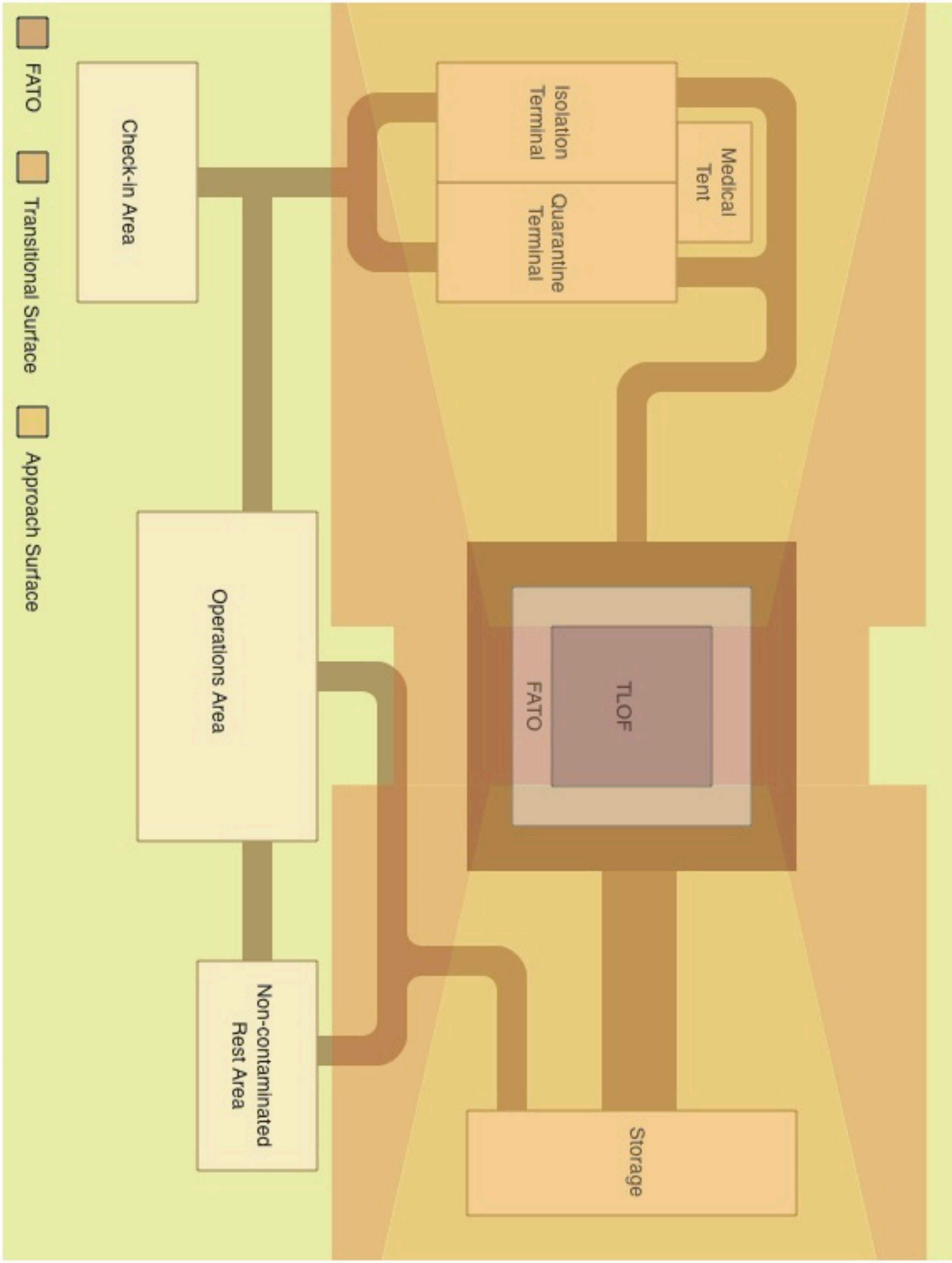


Figure 22: ERRA Proposed Layout with Overlaying Imaginary Surfaces

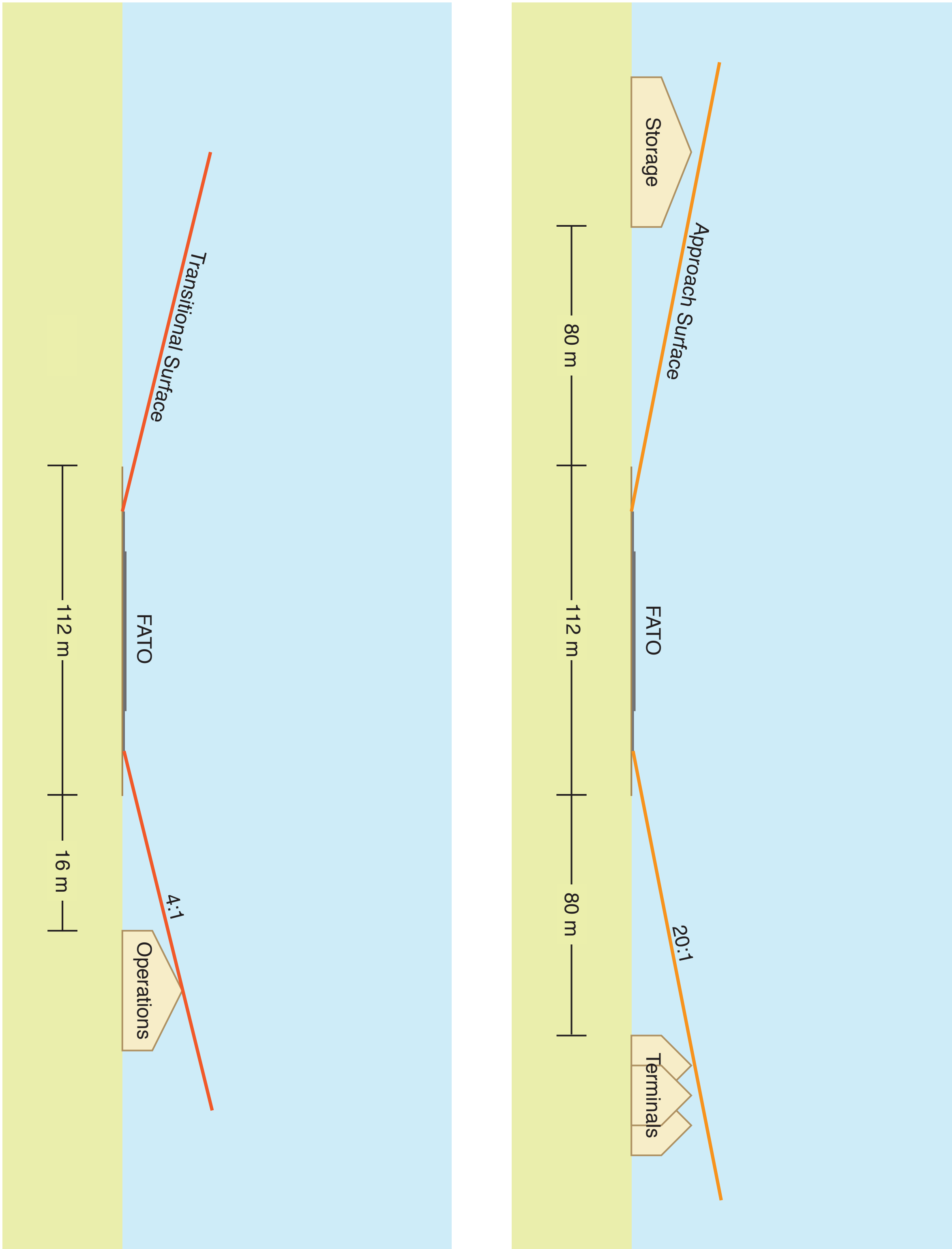


Figure 23: Horiztontal View of Proposed ERRA with Imaginary Surfaces

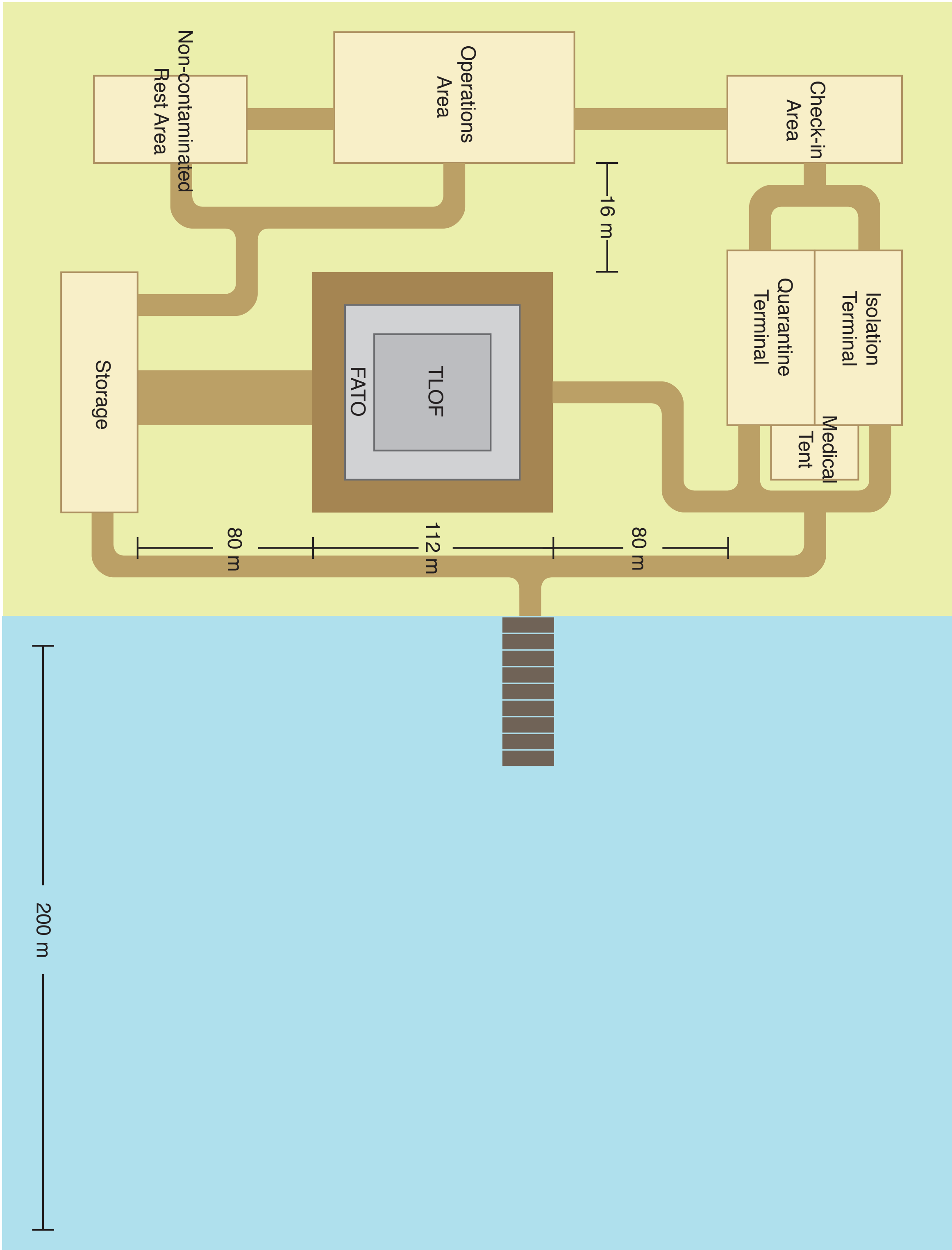


Figure 4: ERRA Proposed Layout near a Body of Water with Minimum Separation Requirements

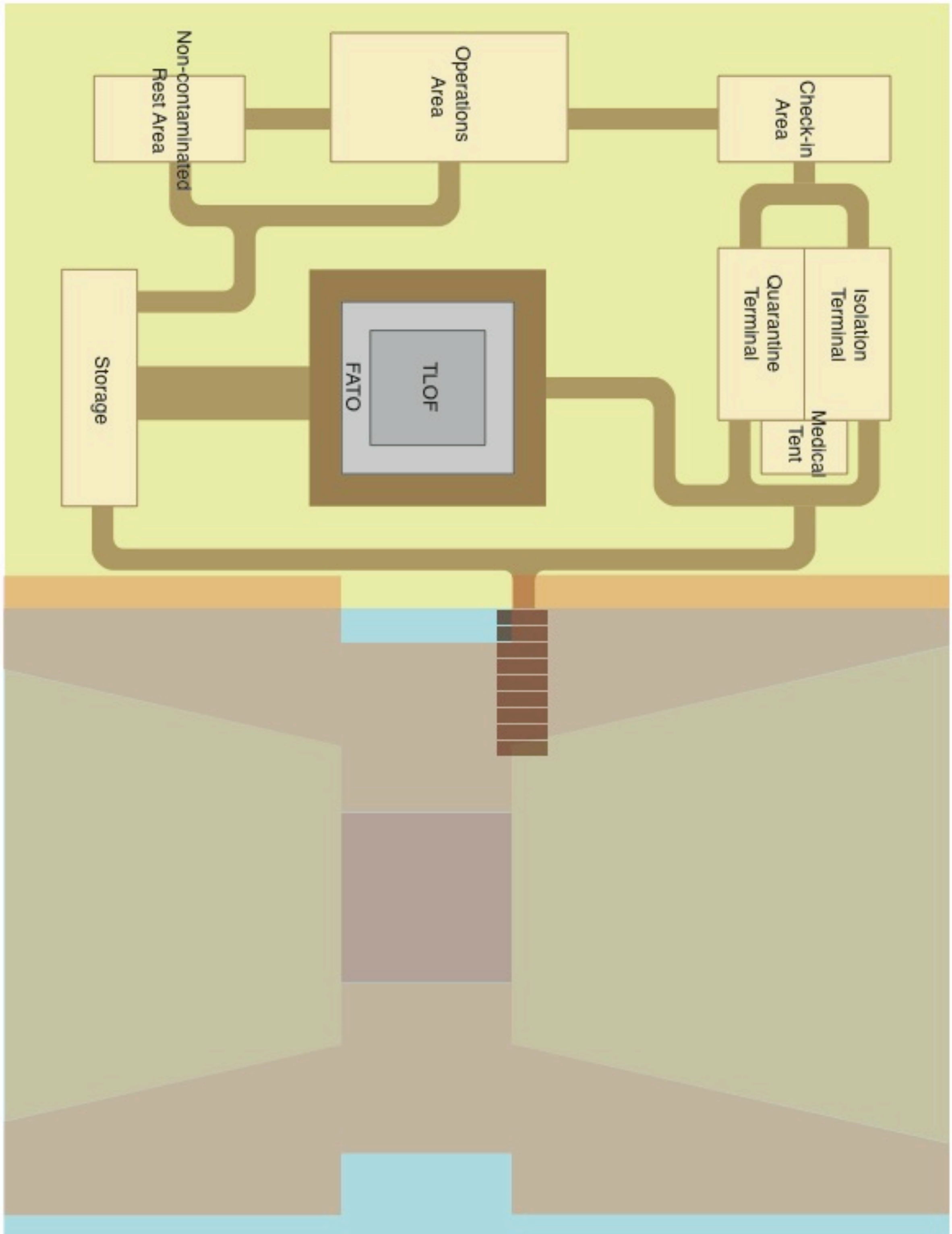
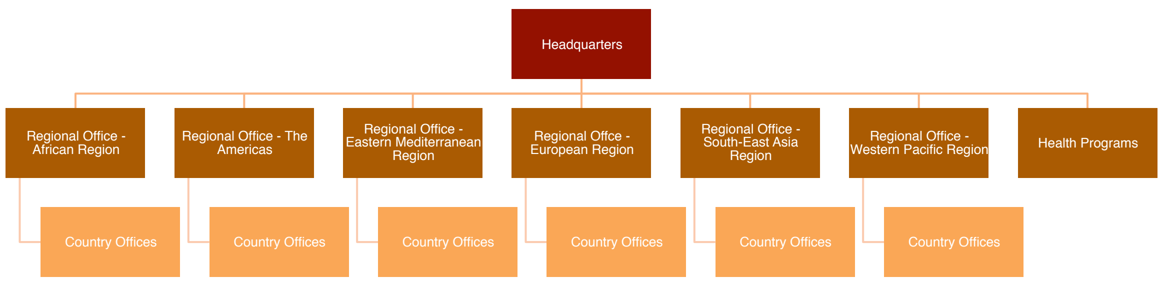


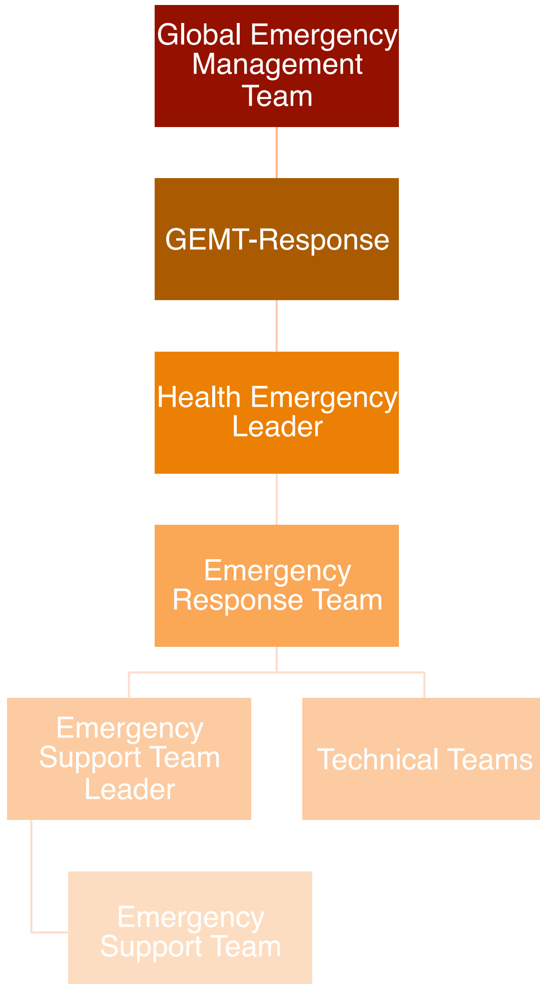
Figure 25: ERRA Proposed Layout near a Body of Water with Overlaying Imaginary Surfaces

Appendix A

Appendix A-1



Appendix A-2


Global Emergency Management Team
GEMT-Response
Health Emergency Leader
Emergency Response Team
Emergency Support Team Leader
Technical Teams
Emergency Support Team

Appendix A-3

Ungraded: an event that is being assessed, tracked or monitored by WHO but that requires no WHO response at the time.

Grade 1: a single or multiple country event with minimal public health consequences that requires a minimal WCO response or a minimal international WHO response. Organizational and/or external support required by the WCO is minimal. The provision of support to the WCO is coordinated by a focal point in the regional office.

Grade 2: a single or multiple country event with moderate public health consequences that requires a moderate WCO response and/or moderate international WHO response. Organizational and/or external support required by the WCO is moderate. An Emergency Support Team, run out of the regional office,[6] coordinates the provision of support to the WCO.

Grade 3: a single or multiple country event with substantial public health consequences that requires a substantial WCO response and/or substantial international WHO response. Organizational and/or external support required by the WCO is substantial. An Emergency Support Team, run out of the regional office, coordinates the provision of support to the WCO.

Appendix A-4

Type of support	GRADE 1	GRADE 2	GRADE 3
Technical	Remote technical assistance from international level	Time-limited missions; remote input to strategic plans; technical advice	In-country on-going technical assistance through surge; issuance of hazard-specific and country specific guidance
Financial	Minimal to none (handled with financial resources available at country level)	Access to regional WHO financial resources; international resource mobilization on request	Access to global and regional WHO financial resources; international resource mobilization and donor outreach
Human Resources	Minimal to none (handled with human resources available at country level)	Surge of emergency experts, as required	Surge team deployed on a no-regrets basis

Appendix A-5

Infection prevention and control measures for care of patients with suspected or confirmed Filovirus haemorrhagic fever in health-care settings	
Standard Precautions	• Use for ALL patients regardless of signs and symptoms • Hand hygiene – with alcohol handrub solutions or soap and running water and single-use towels ○ Before donning gloves and wearing personal protective equipment (PPE) upon entry to the isolation room/area; before any clean or aseptic procedures is being performed on a patient; after any exposure risk or actual exposure with a patient's blood or bodily fluids; after touching (even potentially) contaminated surfaces, items, or equipment in the patient's surroundings; and after removal of PPE, upon leaving the isolation area.
Isolation	• **Isolate** suspected cases in single isolation rooms or cohort them in specific confined areas, separate from confirmed cases. Ensure at least 1 metre (3 feet) distance between patient beds. Dedicate care equipment to suspected cases only and ideally, to each patient.
Assignment & Access	• **Exclusively assign** clinical and non-clinical staff to care areas. Restrict access of all others to dedicated areas.
Personal Protective Equipment (PPE)	• **Strict use of PPE** ○ Prior to entering care areas, don PPE - this includes gloves, an impermeable long-sleeve gown, boots/closed-toe shoes with overshoes, and a mask and eye protection for splashes. ○ Perform careful removal of PPE to avoid contamination of any area of the face (i.e. eyes, nose, or mouth) or non-intact skin.
Injection, sharp & phlebotomy safety	• **Limit the use of needles and other sharp objects**, cover abrasions, and wear PPE. • **Dispose of** sharps safely in appropriate, puncture-resistant containers.
Environmental cleaning, waste & linen disposal	• **PPE** (as detailed above) including heavy duty/rubber gloves should be worn by cleaners. • **Clean surfaces** at least once a day with clean water and detergent and follow additional instructions below for contaminated surfaces. • **Contaminated surfaces –** as soon as possible, clean and then use standard hospital disinfectant (e.g. a 0.5% chlorine solution or a solution containing 1000 ppm available free chlorine). • **Soiled linen** from confirmed or suspected cases should be placed in clearly-labelled, leak-proof bags or buckets and transported to the laundry. Scrape away solid excrement (i.e. faeces or vomit), wash with detergent and water, rinse and then soak in 0.05% chlorine for approximately 30 minutes.
Laboratory safety	• **Ensure safe handling of laboratory samples**, i.e. use of PPE, safe collection and sample processes from confirmed or suspected cases.
Safe care of the dead	• **Keep the handling of human remains and dead bodies to a minimum. Wear PPE.** • Only trained staff should undertake the recommended procedures for burial while taking into account cultural and religious concerns.
Exposure incidents	• **Evaluate, care for,** and if necessary, **isolate** health-care workers or any person exposed to blood or body fluids from confirmed or suspected patients.
The actions described here must be supported by: ongoing surveillance of cases, appropriately assigned roles and responsibilities, the availability of supplies, staff and visitors' training, and the effective use of reminders e.g. posters displayed in key clinical areas.	
From: Interim Infection Prevention and Control Guidance for Care of Patients with Suspected or Confirmed Filovirus Haemorrhagic Fever in Health-Care Settings, with Focus on Ebola. Geneva: World Health Organization, 2014. Available at http://www.who.int/csr/resources/publications/ebola/filovirus_infection_control/en/	

Appendix A-6

Declaration of Health

To be completed and submitted to the competent authorities by the captain arriving from foreign airports.

Submitted at the airport of …………………………………………. .. Date …………

Name of navigation vessel ……........……...… Registration/IMO No ....
arriving from …….……flying to ....

(Nationality)(Flag of vessel) ……………………………………
Captain's name ....

Gross tonnage (aircraft) ……………..

Tonnage (inland navigation vessel) …………………

Valid Sanitation Control Exemption/Control Certificate carried on board?
Yes .... No …......... Issued at …....….…… date ……..........

Re-inspection required? Yes ……. No …….

Has aircraft/vessel visited an affected area identified by the World Health Organization? Yes ..... No …..

Port and date of visit ………………………….……........................

List ports of call from commencement of voyage with dates of departure, or within past thirty days, whichever is shorter:

....
....

Upon request of the competent authority at the airport of arrival, list crew members, passengers or other persons who have joined aircraft/vessel since international voyage began or within past thirty days, whichever is shorter, including all airpots/countries visited in this period (add additional names to the attached schedule):

(1) Name …………………………………
joined from:
(1) …………..……....…..
(2) …...…..……………..
(3) ....

(2) Name …………………………………
joined from:
(1) ……………………........
(2) ……………….............
(3) ....

(3) Name …………………………………
joined from:
(1) ……………………........
(2) ……………….............
(3) ....

Number of crew members on board …………

Number of passengers on board ……………

Health questions

1. Has any person died on board during the voyage otherwise than as a result of accident? Yes .... No …..

If yes, state particulars in attached schedule. Total no. of deaths ....

2. Is there on board or has there been during the international voyage any case of disease which you suspect to be of an infectious nature? Yes........ No….....
   If yes, state particulars in attached schedule.

3. Has the total number of ill passengers during the voyage been greater than normal/expected? Yes .... No …..
   How many ill persons? ....

4. Is there any ill person on board now? Yes .... No …..... If yes, state particulars in attached schedule.

5. Was a medical practitioner consulted? Yes .... No …... If yes, state particulars of medical treatment or advice provided in attached schedule.

6. Are you aware of any condition on board which may lead to infection or spread of disease? Yes .... No ….....
   If yes, state particulars in attached schedule.

7. Has any sanitary measure (e.g. quarantine, isolation, disinfection or decontamination) been applied on board?
   Yes .... No …... If yes, specify type, place and date:
   ....

8. Have any stowaways been found on board? Yes .... No …... If yes, where did they join the ship (if known)?
   ....

9. Is there a sick animal or pet on board? Yes .... No ....
   Note: In the absence of a surgeon, the master should regard the following symptoms as grounds for suspecting the existence of a disease of an infectious nature:
   a. fever, persisting for several days or accompanied by (i) prostration; (ii) decreased consciousness; (iii) glandular swelling; (iv) jaundice; (v) cough or shortness of breath; (vi) unusual bleeding; or (vii) paralysis.
   b. with or without fever: (i) any acute skin rash or eruption; (ii) severe vomiting (other than sea sickness); (iii) severe diarrhoea; or (iv) recurrent convulsions.

I hereby declare that the particulars and answers to the questions given in this Declaration of Health (including the schedule) are true and correct to the best of my knowledge and belief.

Signed ………………………………………

Master

Countersigned ………………………………………

Ship's Surgeon (if carried)

Date ………………………………………

Appendix B | Acronyms

A

ANPC | Advanced Navigation and Positioning Corporation

C

CCTV | Closed Circuit Television

CDC | Center for Disease Control

CPDLC | Controller Pilot Data Link Communication

D

DWB | Doctors Without Borders

E

ERF | Emergency Response Framework

ERRA | Emergency Rapid Response Airport

ERT | Emergency Response Team

F

FAA | Federal Aviation Administration

FATO | Final Approach Touchdown Liftoff Surface

G

GEMT | Global Emergency Management Team

GEMT-R | Global Emergency Management Team - Response

GEO | Geostationary Earth Orbit

GPS | Global Positioning System

H

HCT | Humanitarian Country Team

HL | Health Emergency Leader

I

IASC | Inter-Agency Standing Committee

IATA | International Air Transport Association

ICAO | International Civil Aviation Organization

IHR I International Health Regulations

ILS I Instrument Landing System

IPC I Infection Prevention Control

IMC I Instrument Meteorological Conditions

IFR I Instrument Flight Rules

IFRC I International Federation of Red Cross and Red Crescent Societies

M

MoH I Ministry of Health

N

NIOSH I National Institute for Occupational Safety and Health

O

OSHA I Occupational Safety and Health Administration

P

PAR I Precision Approach Radar

PHEIC I Public Health Emergency of International Concern

PPE I Personal Protective Equipment

S

SCBA I Self Contained Breathing Apparatus

SBAS I Satellite-Based Augmentation System

T

TLOF I Touchdown and Take-Off Surface

TLS I Transponder Landing System

TTLS I Transportable Transponder Landing System

U

UAS I Unmanned Aircraft Systems

UHF I Ultra High Frequency

UN I United Nations

UNCT I United Nations Country Team

V

VHF | Very High Frequency

VFR | Visual Flight Rules

VMC | Visual Meteorological Conditions

VOTL | Vertical Take-Off Landing

W

WAAS | Wide Area Augmentation System

WCO | World Health Organization Country Office

WHO | World Health Organization

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