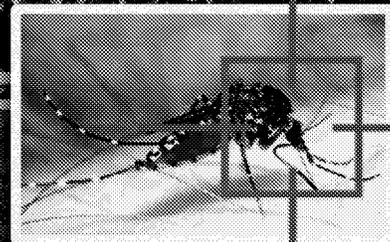


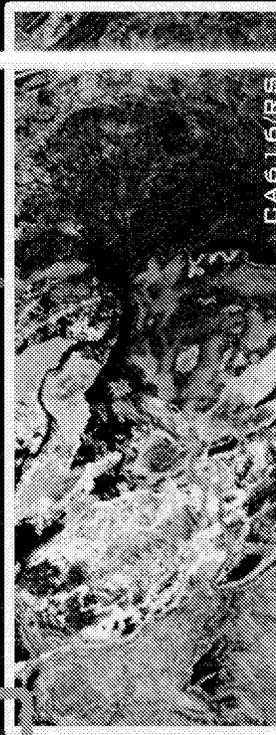
HI-STAR

HEALTH IMPROVEMENTS THROUGH
SPACE TECHNOLOGIES & RESOURCES

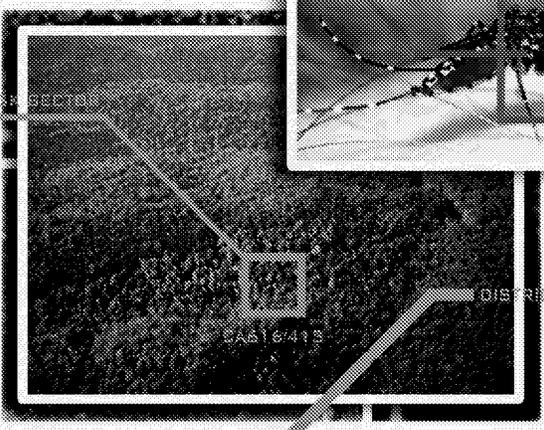
EXECUTIVE SUMMARY



HIGH MALARIA RISK SECTOR

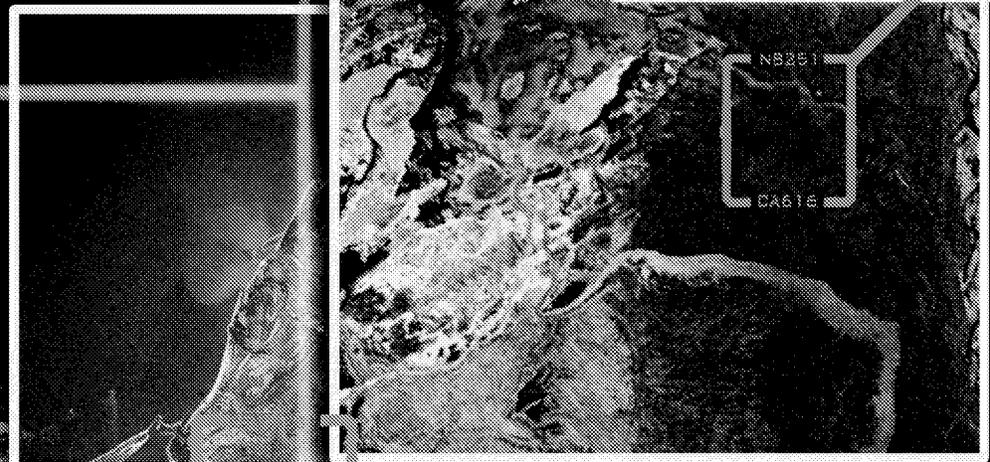


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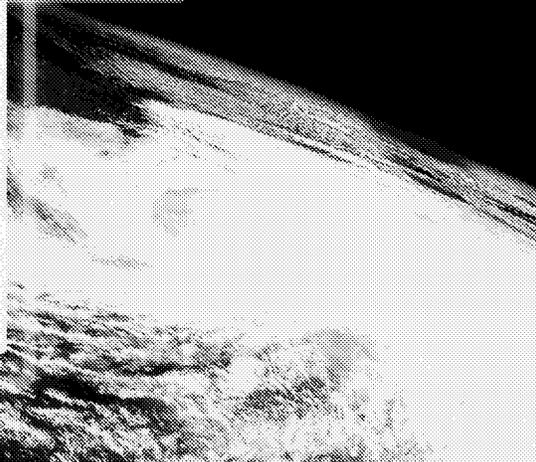
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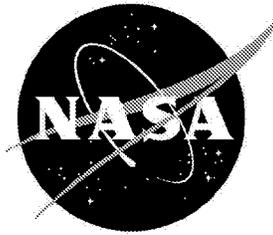
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African children at risk of malaria. Photo courtesy of the World Health Organization

When Malaria Hits Home

At first, Maria thought she had the flu. She felt so tired, her muscles ached and although she had a fever, she felt chilled all the time. Despite her woes, the mother of seven persevered and continued working the long hard days to which she had become accustomed. But it didn't take long before her condition worsened. Eventually, her head hurt so badly that she could no longer work in the field with her family. Maria was forced to rest in bed. Then the nausea hit. Her whole body shook while beads of sweat seeped into the bed. Maria called out and writhed in pain. Her young daughter stayed home to tend to her ailing mother.

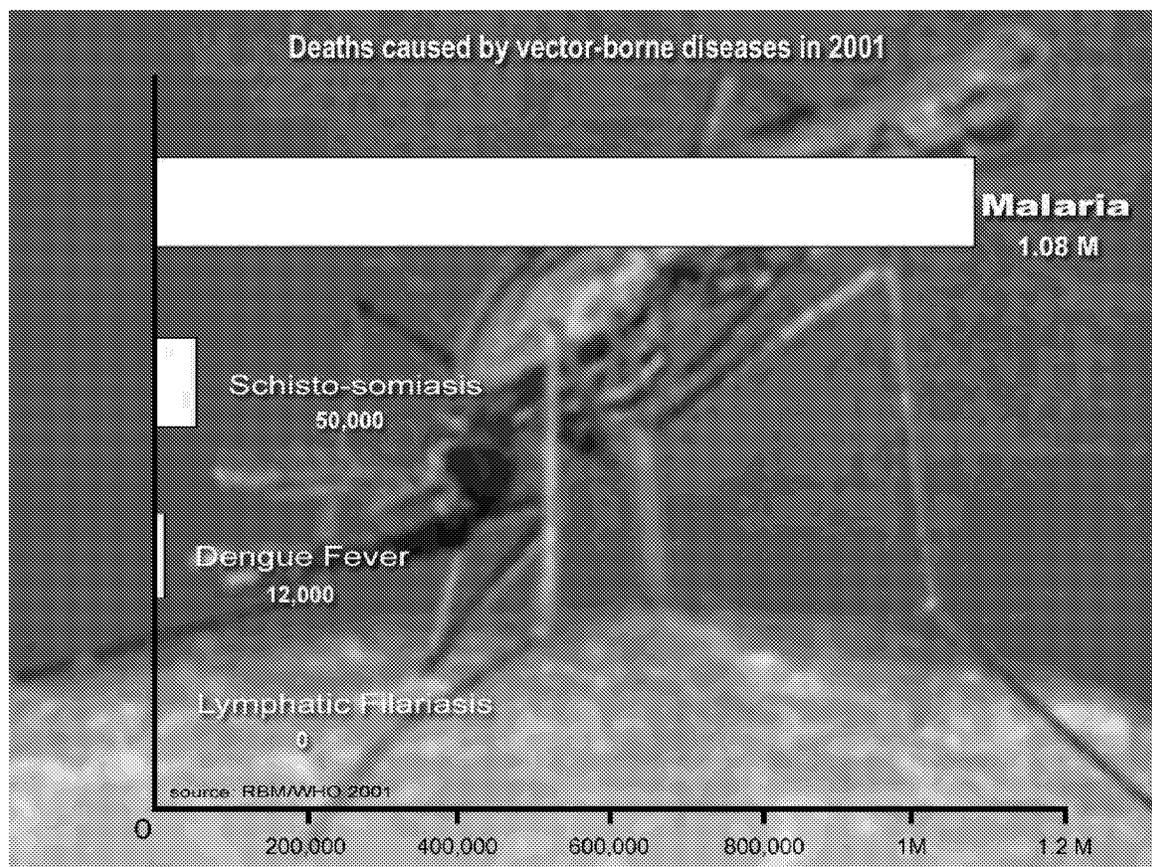
Maria's husband furrowed his brow as he looked at his young wife. Her usually beautiful dark skin looked pale and yellow. It was a color he had seen before – it was the color of death. He placed his head in his hands and wept quietly. His own parents had died of malaria when he was just a boy so he knew the symptoms well. And just this year he and Maria had lost their beloved baby boy to the disease. The child had suffered obscene bouts of diarrhea before the seizures started and he went into a coma. He had died shortly after. Surely not Maria too. Surely not Maria.

This account is based on a true story. Malaria causes more than 300 million acute illnesses and at least one million deaths annually. Approximately 40% of the world's population is at risk of malaria. Every single second of every single day, ten people are infected with malaria. Many of these cases involve children who do not survive [Roll Back Malaria and the World Health Organization, 2002].

A Dangerous Disease

The word malaria comes from the Italian *mala aria* or bad air because it was once thought the disease came from breathing unhealthy swamp air [Wernsdorfer, 1980]. We have since learned that malaria is a parasitic disease spread by the female *Anopheles* mosquito. When the mosquito bites an infected person, it ingests microscopic malaria parasites living in the person's blood. The mosquito then transmits the disease to other humans.

Malaria affects the health and wealth of individuals and nations alike. It is both a disease of poverty and a cause of poverty. It has measurable direct and indirect costs, and has recently been shown to be a major constraint to economic development. This has meant that the gap in prosperity between countries with malaria and those without has become wider every year.



Malaria Moving North

Malaria was once even more widespread throughout the world, but it was successfully eliminated from many countries with temperate climates during the mid 20th century. Today, malaria is predominately found throughout the tropical and sub-tropical regions of the globe. Over the past ten years, malaria outbreaks have started moving back into the northern hemisphere. Cases have been reported in northern India, Turkey and Russia. Occasional outbreaks have also been reported in Europe and North America [RBM/WHO, 2002].

Malaria transmission is possible when weather conditions support the growth of *Anopheles* mosquitoes. When people arrive from malaria-endemic countries, a malaria parasite reservoir becomes available in non-infected areas.

Short-term climate variations such as El Niño-Southern Oscillation (ENSO) also affect the distribution and intensity of malaria in some regions. El Niño is a disruption of the balance of the ocean-atmosphere in the tropical pacific, which affects the weather and climate. Long-term changes such as global warming may also influence the emergence of malaria, which tends to increase with temperature changes.

Malaria, despite all of its devastating consequences, is a preventable disease. This report, Health Improvements through Space Technology And Resources (HI-STAR) demonstrates one way this can be done.

HI-STAR

If you think you are too small to make a difference, try sleeping in a closed room with a mosquito.

– African Proverb

Like the tiny yet powerful mosquito, HI-STAR is a small program that aspires to make a difference. Timely detection of malaria danger zones is essential to help health authorities and policy makers make decisions about how to manage limited resources for combating malaria.

In 2001, the technical support network for prevention and control of malaria epidemics published a study called "Malaria Early Warning

Systems; Concepts, Indicators and Partners." This study, funded by Roll Back Malaria, a World Health Organization initiative, offers a framework for a monitoring and early warning system. HI-STAR seeks to build on this proposal and enhance the space elements of the suggested framework. It is the work of fifty-three professionals and students from the International Space University's 2002 Summer Session Program held in California, USA.

Our mission is to develop and promote a global strategy to help combat malaria using space technology



HI-STAR focuses on malaria because it is the most common and deadly of the vector-borne diseases. Malaria also shares many commonalities with other diseases, which means the global strategy developed here may also be applicable to other parasitic diseases.

HI-STAR would like to contribute to the many malaria groups already making great strides in the fight against malaria. Some examples include: Roll Back Malaria, The Special Program for Research and Training in Tropical Diseases (TDR) and the Multilateral Initiative on Malaria (MIM). Other important groups that are among the first to include space technologies in their model include: The Center for Health Application of Aerospace Related Technologies (CHAART) and Mapping Malaria Risk in Africa (MARA).

Malaria is a complex and multifaceted disease. Combating it must therefore be equally versatile. HI-STAR incorporates an interdisciplinary, international, intercultural approach.



An Interdisciplinary, International, Intercultural Initiative

A single solution for malaria may never exist. As a result, combating this disease requires a combination of tools that range from Earth observation satellites to airborne and ground-based measures including pesticides, bed nets and various medical treatments.

HI-STAR is interdisciplinary in that it addresses all aspects of malaria from a scientific, engineering, economic, medical, regulatory, social, political and organizational perspective. It recognizes and addresses the complex interactions among specialties.

Our concept is international. It is an approach developed by an international group of professionals and students, including people from developing countries, who understand the complexities of working within and among many nations. The strategy, while global in structure, has been designed to meet the individual needs of specific regions.

HI-STAR is intercultural. It is based on a strategy that can be applied to countries with distinct histories, religions and traditions. HI-STAR seeks to unite people in preventing malaria using a global framework. The strategy is flexible, however, in that it allows individual regions to use a unique local approach. HI-STAR's global strategy is general in principle and highly customizable in practice.

Why Space Technology?

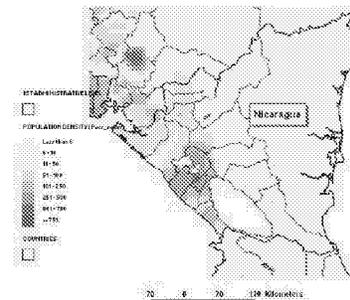
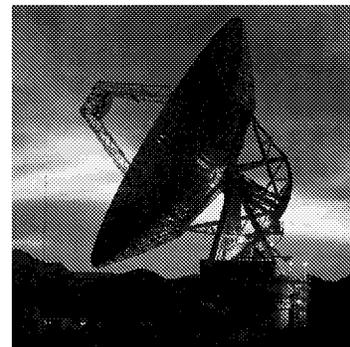
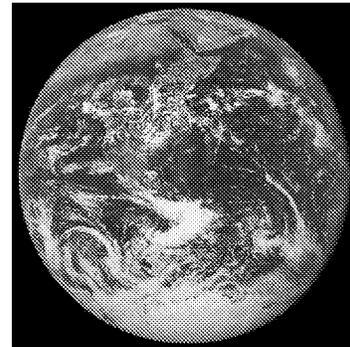
From space, we can see the Earth is united, undivided by borders, unrestrained by political boundaries. The transnational nature of space mirrors the transnational nature of vector-borne diseases, which are spreading indiscriminately irrespective of national frontiers.

By looking at the globe from space, we achieve a new perspective. We can see things that would not be possible to view up close. Earth observation technologies have been used for many years and have been implemented for a wide range of purposes. They are most commonly used for monitoring natural resources, agriculture, oceanography, mapping the weather and natural disasters.

Other space technologies such as Global Navigation Satellite Systems (GNSS) may support malaria monitoring. For example, it is possible to locate infected areas and treatment facilities in remote regions.

Malaria disease dynamics and distributions are related to environmental variables. Water observation is key because mosquitoes lay their eggs in stagnant bodies of water. Weather plays an important role in the quantity and distribution of *Anopheles* mosquitoes, which transmit diseases.

High temperatures, humidity, precipitation and wind promote infestations of these dangerous insects. Temperature determines



the rate at which mosquitoes develop into adults, the frequency of their blood feeding, the rate at which the parasites are acquired and the incubation time of the parasite [Patz et al., 2000].

With remote sensing images, we can monitor environmental conditions that support the growth of mosquito populations. The information gathered this way is of limited value, but integrating it in a Geographic Information System (GIS) makes it a useful tool. Figure 1 depicts the data that would feed into such a system.

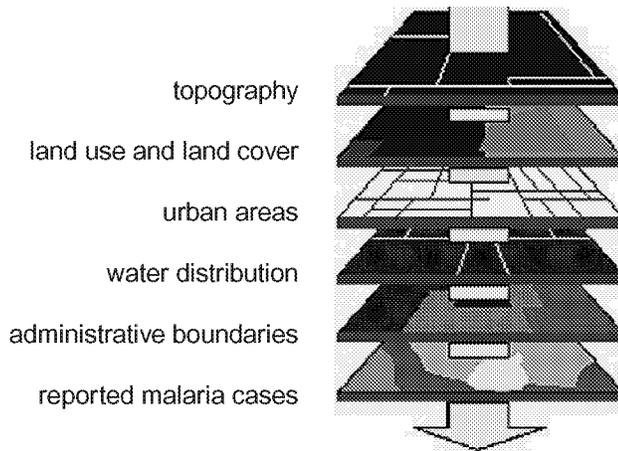
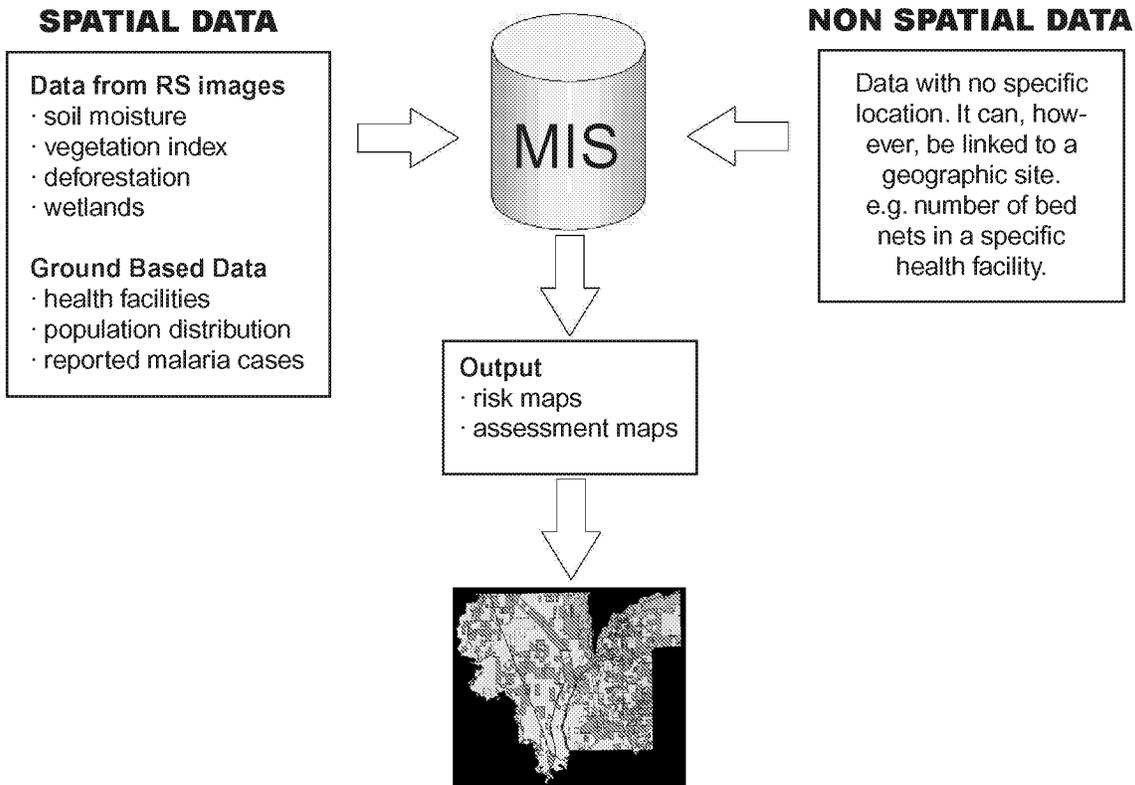


Figure 1: Malaria specific GIS data structure

Malaria Information System

GIS is an information system that assembles, stores, manipulates and displays spatial data. By integrating malaria specific information in a GIS, a Malaria Information System (MIS) can be developed. A model of the system is shown in Figure 2.



source: CHAART, NASA Ames research center website

Figure 2: Malaria Information System

Integrating environmental data gathered by remote sensing satellites enhances the system and helps create:

- low cost risk maps
- weather forecasts that provide malaria early warnings

HI-STAR suggests developing a MIS as a low cost tool to help organizations plan their efforts to fight malaria. The success of risk monitoring is only as effective as the ability to transmit information to those who can put preventive measures in place. MIS seeks to develop an information product that links the technical to the interpersonal by presenting data in a comprehensive form.

How MIS findings are presented is a key component of the model. Malaria risk maps are of little use if they are not understood. All MIS output must be simplified and comprehensively communicated. This can be done using attractive illustrations and graphs.

MIS findings should also be customized according to individual user needs and requests. Users will be encouraged to offer feedback so that MIS outputs can be enhanced to meet specific requirements. Feedback will help customize MIS so that it is useful in diverse regions with unique concerns.

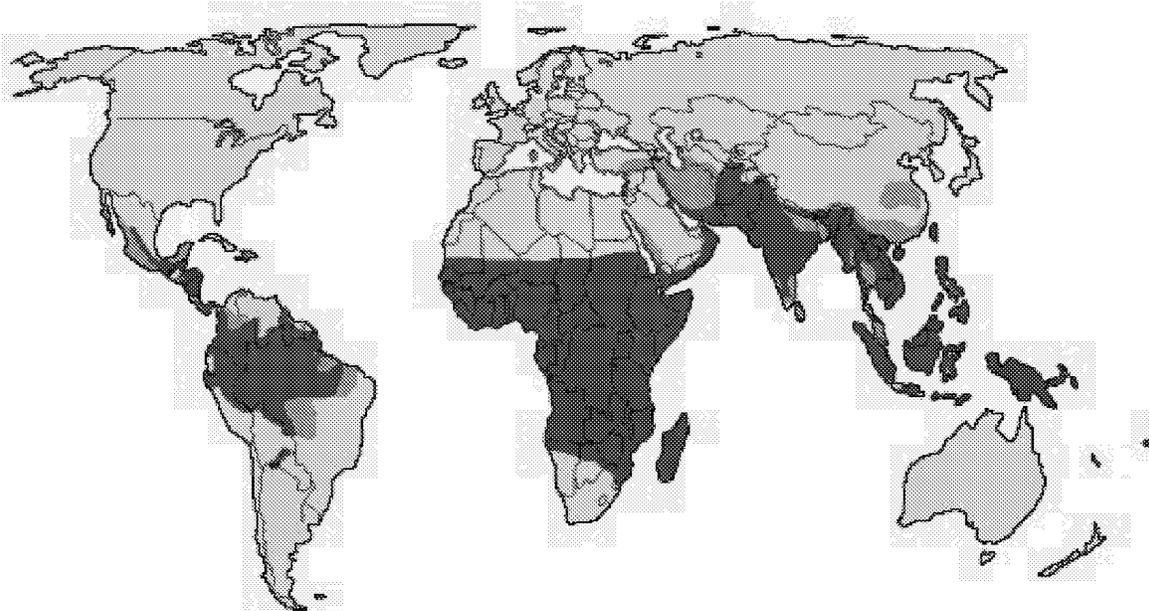
In the past, the costs of using remotely sensed space images were too high for such an application. However, reduced data costs and improved image and GIS software are bringing down these expenses.

HI-STAR Strategy

Our strategy recommends the increased use of space technology in conjunction with current initiatives. We seek to link the information from space technology to the people who need it most in a timely and comprehensive form so that health authorities and policy makers can manage resources for combating malaria more effectively.

For a strategy to succeed, it must meet the needs of those involved. In the spirit of HI-STAR's interdisciplinary, international, intercultural design, we studied the situation of a number of malaria endemic countries.

The vast majority of the world's population lives in Asia where malaria risk is significant. Yet 90% of all malaria cases remain in Africa [RBM/WHO, 2002]. We studied two countries from each region. Countries were chosen based on three factors, malaria burden, population at risk, and space infrastructure.



WHO malaria distribution map 2001

In an effort to achieve a complete picture, we looked at countries with varying circumstances. In Asia, we selected India and Indonesia and in Africa, we chose Nigeria and Kenya.

India has a population of 1 billion people where about 98% of the population is at risk of malaria. It has an extensive space program that remains unused for malaria risk mapping.

Indonesia is the world's fourth most populous country with 200 million people where 35% of the population is at risk of malaria. Indonesia was the first developing country to have its own satellite communication system, but it does not currently use this system for malaria information transfer.

Nigeria is the most populated country in Africa with 126 million people. Over 90% of the population in Nigeria lives in malaria-invested areas. The Nigerian Space Agency (NASRDA) is still in its very early stages. The space program is being developed in part to benefit health, education and economic stability. NASRDA does not yet do any malaria mapping.

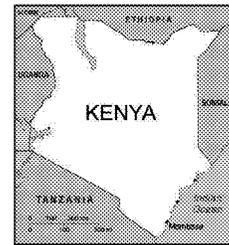
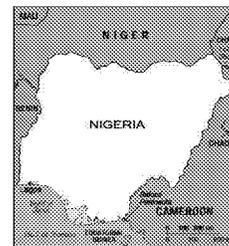
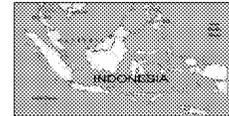
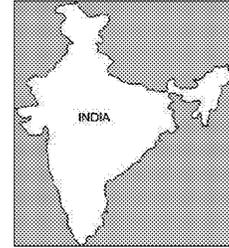
Kenya has a population of over 30.7 million people where 65% of the population is at risk. Kenya does not have a space program, but it does have a limited space infrastructure that has participated in some malaria mapping initiatives.

While progress in combating malaria has been made, these case studies identified a great need for malaria risk mapping and effective information transfer. A solution that may be effective in India, may not be appropriate in Indonesia or Nigeria or Kenya. HI-STAR is a strategy that could benefit each of these countries. It is part of a global approach that can be customized to meet individual needs.

Implementing the HI-STAR Strategy

While reviewing existing programs, we identified three major constraints that groups may face when seeking to implement HI-STAR. These limitations include cost, lack of resources and lack of technical capability. While these constraints cannot be easily overcome, we will attempt to address them, at least in part, in our implementation strategy. The goal of the HI-STAR strategy is to integrate MIS into existing programs or organizations to maximize resources and capabilities. We suggest a two-phase approach:

- 1) a development and qualification phase
- 2) an operational phase



During the development and qualification phase, we recommend space agencies take the lead and develop MIS working closely with the World Health Organization to determine user needs. To develop MIS, space agencies should combine current GIS data with information from existing programs such as CHAART. Once the system is in place, the agencies should obtain regular feedback to ensure the information is relevant.

During the operational phase, we suggest groups such as Roll Back Malaria and the World Health Organization take the lead to ensure specific countries can in fact receive, generate and disseminate information. We therefore recommend that Roll Back Malaria and the World Health Organization operate the system with technical support from space agencies. These groups will need to:

- verify capability and access satellite data
- ensure personnel are trained to input and gather data
- establish infrastructure to disseminate data
- set up processing centers in existing space or health related facilities

HI-STAR seeks to limit costs by depending on existing resources within established organizations.

Costs

The cost of the HI-STAR strategy ranges greatly in conjunction with the specific needs of the individual organization or country. Initial investments are related to the following:

- cost of MIS development
- fee of establishing processing facilities in existing regional centers
- rate for setting up a small coordination center
- expense of developing communications capabilities

We estimate the startup cost of MIS, including information dissemination, in a small country such as Kenya would be about USD \$2.5 million. In a large country such as India, which would

require a great number of dissemination centers, that number would jump to about USD \$14 million. The main cost drivers are the expense of new regional centers, the number of existing dissemination centers and the price of developing communications capabilities in areas where the current infrastructure is insufficient.

Although these costs may appear initially restrictive, the benefits realized by implementing HI-STAR are significant both financially and socially. HI-STAR will ensure a more efficient distribution of limited malaria prevention and treatment resources.

Continuing Fight Against Malaria

Malaria will continue to be a very serious global health problem requiring scientific, technical, institutional and financial solutions. Worldwide incidence of malaria has quadrupled over the past five years and resistance to available drugs is growing rapidly. Malaria prevention is becoming more important than ever.

Space technologies and resources provide malaria early warnings that enable health authorities and policy makers plan their efforts to fight the disease. HI-STAR recommends the increased use of space technology in conjunction with current initiatives. We seek to link the information from space technology to the people who need it most so they can combat vector-borne diseases even more effectively. What would a world without malaria look like?



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