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The AGRHYMET Data Communications Project

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ABSTRACT

The U.S. Geological Survey (USGS) and the U.S. Agency for International Development (USAID) are providing technical assistance to the AGRHYMET program in West Africa. AGRHYMET staff use remote sensing technology to produce satellite image maps of the Sahel region of West Africa. These image maps may show vegetation greenness, sea surface temperatures, or processed weather satellite imagery. The image maps must be distributed from the AGRHYMET Regional Center in Niger to national AGRHYMET centers in the member countries of Burkina Faso, Cape Verde, Chad, Gambia, Guinea-Bissau, Mali, Mauritania, Niger, and Senegal. After consideration of a number of land- and space-based solutions for image map distribution, the best solution was determined to be use of International Maritime Satellite Organization (INMARSAT) land-based terminals. In April 1992, a field test and proof-of-concept demonstration using land-mobile terminals produced favorable results.

The USGS and USAID are setting up a wide area network using INMARSAT terminals to link the AGRHYMET sites for image data transfer. The system is in the procurement and installation phase and initial operating capability may be operational for the 1993 growing season, starting in May 1993.

INTRODUCTION

In the middle 1970's, the World Meteorological Organization, in cooperation with nine member nations in the Sahel region of western Africa, organized the AGRHYMET program to help the member nations increase agricultural crop production. [1] The role of AGRHYMET has since expanded to include supplying food production advice to government ministries, locust plague prediction and control, and assistance to the Famine Early Warning System program. To accomplish its mission the AGRHYMET program has set up the AGRHYMET regional center (ARC) in Niamey, Niger, and national AGRHYMET centers (NAC) in each of the member nations. A receiving station for satellite images from NOAA's Advanced Very High Resolution Radiometer (AVHRR) instrument was installed at the ARC by the French Government as part of its foreign aid program. The U.S. Agency for International Development (USAID), in cooperation with the U.S, Geological Survey's EROS Data Center (EDC), have set up a system to process the AVHRR data to make image maps that indicate the relative "greenness" of the area. Greenness maps are derived from the Normalized Difference Vegetation Index (NDVI) computed from AVHRR data. [2] They are distributed in hard copy format from the ARC to the NAC's via the mail system on 10-day intervals throughout the growing season. At present, the delivery of the greenness maps does not occur in a timely manner to support near-realtime assessment of crop production for policy decisions. It was proposed that a telecommunications system be installed to transfer the greenness maps electronically, in near-realtime.

REQUIREMENTS

The telecommunications system is required to provide a computer-to-computer communications link to transfer the greenness map data from the ARC to the NAC's and for the NAC's to transfer weather data back to the ARC. The system will operate primarily during the growing season and transfer data on 10-day intervals (decadal) between the

ARC and the NAC's. The system technical requirements are summarized as follows:

1. The system shall provide operational data transfer of greenness map image files ranging up to 4 MB from the ARC to a NAC. Other data sets and files may be added in the future as required.

2. Weather data ranging up to 500 KB shall be transferred from a NAC to the ARC.

3. The system shall be operational for the 1993 growing season and remain operational for 5 years.

4. Equipment installed at the ARC or a NAC shall be supported by ARC personnel for hardware and software maintenance and repair. The vendor will provide warranty service for the system's operational life of 5 years.

5. The transmission channel [or "telephone"] service shall be an operational system, using the same provider or service for the full 5 years of operation.

6. The system shall minimize the annual recurring costs of operation.

7. The system shall provide moderate growth capability to accommodate changing AGRHYMET requirements and services.

8. The system shall not require any special licensing or permits.

9. The system shall provide 99% availability during the growing season (i.e. – unaffected by storms, power outages, or fluctuations in local telephone service quality).

CANDIDATE SOLUTIONS

A number of techniques were examined, ranging from point–to–point digital radios to satellite communications systems, with a satellite system being the optimum choice. All ground–based systems were eliminated from consideration because of line–of–sight requirements or low data rate capacity. A diagram of a typical satellite–based system is shown in figure 1.

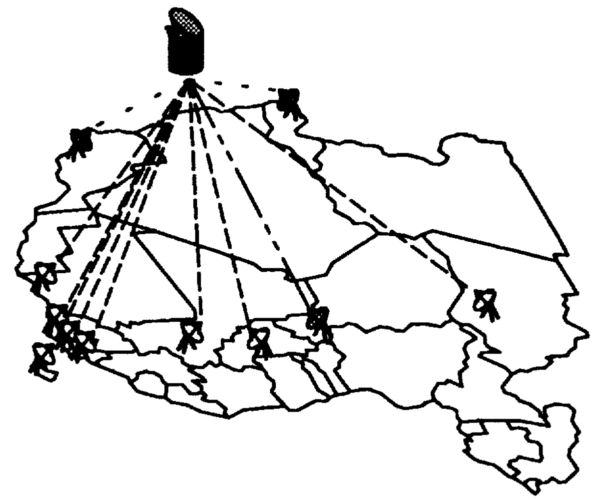

Figure 1. A Satellite–Based System

Among the satellite systems, most privately owned systems were eliminated due to lack of coverage over the Sahel or the uncertainty of continuing service for the 5 year project lifetime. This narrowed candidate systems to satellites operated by two international consortiums, INTELSAT (the International Telecommunications Satellite Consortium) and INMARSAT (the International Maritime Satellite Organization). Between the two systems, the INMARSAT approach was selected on the basis of being appropriate for AGRHYMET requirements, initial cost, recurring costs, and ease of operation and maintenance. A summary of the requirements criteria is shown in **table 1**.

INMARSAT System

The INMARSAT system consists of four satellites in geostationary orbits providing global coverage (figure 2). INMARSAT provides voice, fax, and data communications services between land–mobile, maritime, and fixed users. The proposed system will use land–based fixed terminals.

The system was originally set up to provide ship–to–shore radiotelephone service, but has since expanded to encompass large numbers of land–mobile users also. The system operates in a manner analogous to a long distance carrier, connecting to either a local phone system or an INMARSAT terminal. Access to the system is similar to a telephone system. A user dials the desired destination (phone number), and the system connects them.

System Configuration

Each site (both ARC and NAC) will use a fixed INMARSAT terminal with an external fixed dish antenna (1 to 2 m in diameter). The terminals will be linked to a dedicated personal computer (provided as part of the system) through FAX/modem. The terminal electronics unit, the personal computer, and an uninterruptible power supply will be located in the site computer room; while the antenna will be located outside the building (typically installed on the roof). The external antenna must be located within 15 m of the terminal electronics unit.

Table 1. Summary of Requirements Analysis

Requirement	INMARSAT	INTELSAT
Operational System	Yes	Yes, some terminal customization may be required
Duplex Link	Yes	Yes
Minimize Interaction Between Local PTT and System	COMSAT/Common Carrier pays fees	Transponder rental requires fees to each PTT, use of existing INTELSAT terminal in Niamey requires leased lines and coordination with PTT(s)
Minimize Licensing	License to enter country and possibly operator's permit, considered to be minimal requirements	Requires coordination with each country's PTT
Supportable by ARC Personnel	Vendor will train ARC personnel, provide spares and extended warranty, easily maintained	Vendor will train ARC personnel, provide spares and extended warranty, special skills required for maintenance and repair
System Life of 5 to 7 Years	Yes	Yes
Sahel Environmental Conditions	Terminals designed for operation in hostile environments	Can be modified to operate in Sahel environment
Initial Operation for 1993 Growing Season	Terminals available from stock	System development at vendor would take 3 to 6 months
Expandability/Growth	Yes, add terminals, add high data option for 56/64 KBPS link	Yes, add terminals, can increase data rate to width of channel, rent wider channel bandwidth to increase data rate
Easily Interface to Existing ARC/NAC Hardware	Yes, interface looks like phone line	Some specialized connection equipment may be required
Satellite Link Available for 5 to 7 Years	Yes, satellite links transparent to user	Yes, may be moved to another satellite as current satellite ages
Minimize Recurring Costs	Pay only 'phone' bill ($20k/yr)	Transponder rental, plus PTT fees

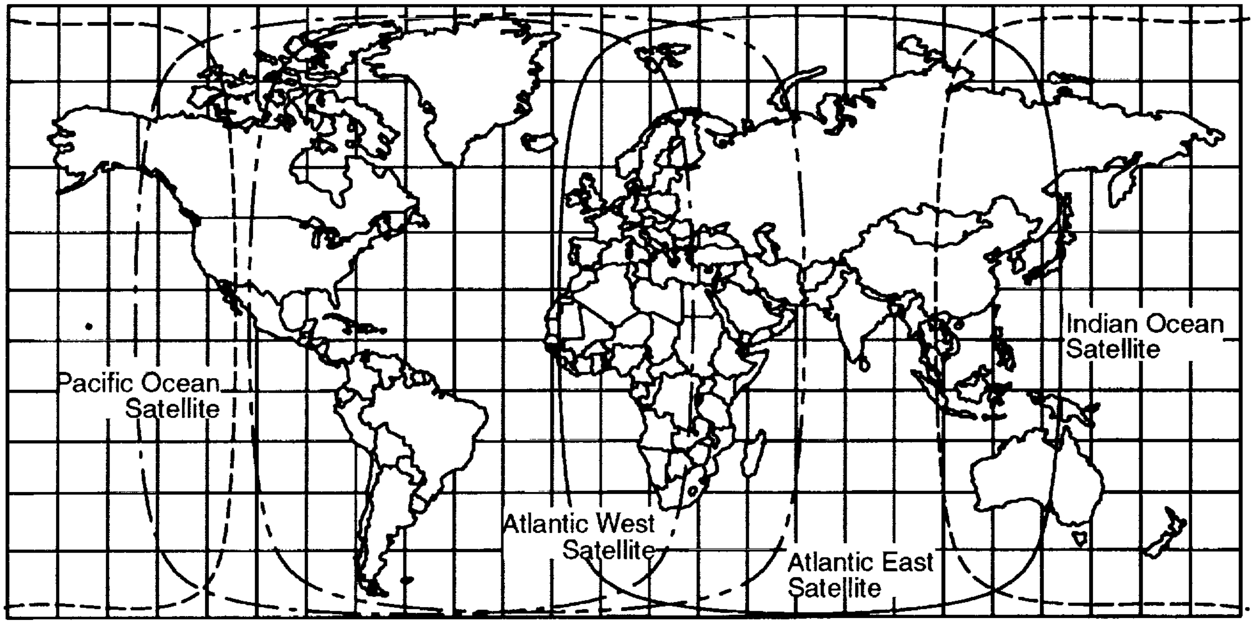

Figure 2. Global INMARSAT Satellite System Coverage

FIELD TEST DESCRIPTION AND RESULTS

A field test with two INMARSAT land–mobile satellite terminals was performed in April 1992. Data was relayed between the ARC in Niamey, Niger, and the NAC in Ougadougou, Burkina Faso, using an INMARSAT coast earthstation to turn the link around (double–bounce through the spacecraft). Transfer rates between 4.8 KBPS and 19.2 KBPS were measured, with the typical rate of 8 KBPS for a large file transfer. A greenness map test file of the West African coast was used, with a typical transmission time of 10 minutes (at an 8 KBPS data rate). Telebit modems were used, along with the MTEZ and Procomm Plus modem control software packages. Although both packages transferred data at acceptable rates, using the KERMIT utility in Procomm Plus yielded the highest sustained data transfer rates.

The system was also used to remotely log into EDC computer systems in the U.S. In most cases the system connected at rates between 2.4 KBPS and 19.2 KBPS, although some of the lower connection rates were imposed by the remote connection, not the INMARSAT link. Voice communication was also used extensively between both the West African sites and the U.S., although the main goal of the test was data transfers. The ARC site is shown in figure 3, and the NAC site is shown in figure 4.

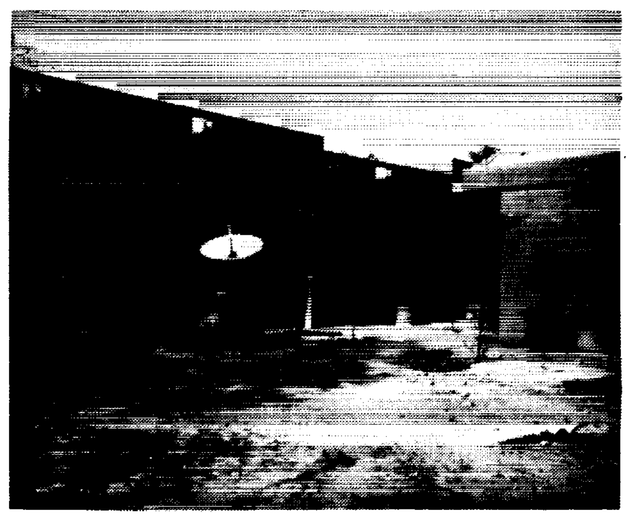

Figure 3. ARC Site in Niamey

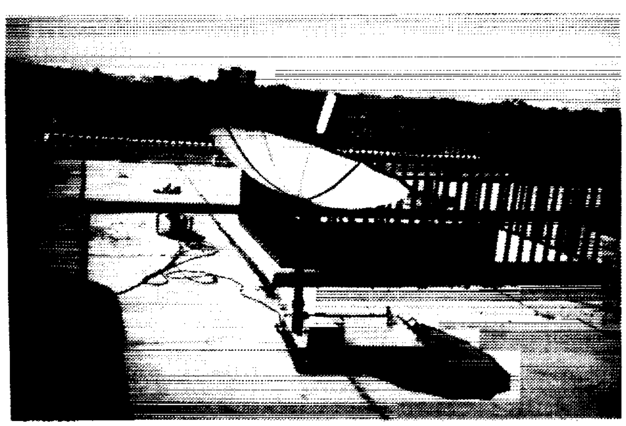

Figure 4. NAC Site in Ougadougou

As a proof of concept test, the INMARSAT system met all requirements. Further optimization of the selection of modems and software may yield higher sustained data rates than the 8 KBPS experienced. Moreover, the use of modems designed specifically for noisy links (i.e. – cellular telephony) may increase the total system throughput.

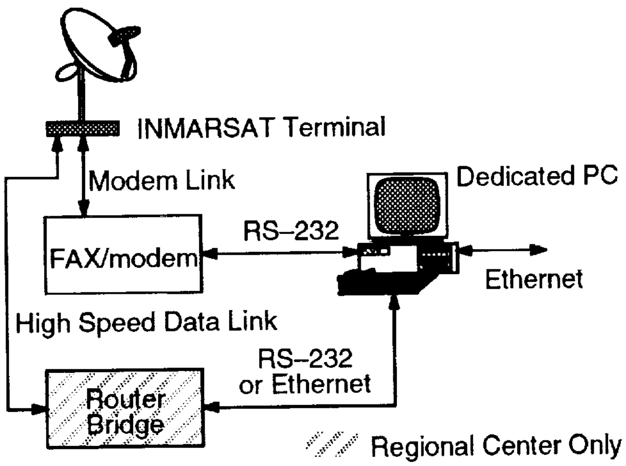

Figure 5. System Configuration

PHYSICAL CONFIGURATIONS

The configuration of the system is shown in figure 5. At the regional center the configuration consists of a INMARSAT terminal, a dedicated personal computer, a FAX/modem, a router/bridge, and an uninterruptible power supply for all the equipment. The national center sites consist of an INMARSAT terminal, a dedicated personal computer, a FAX/modem, and an uninterruptible power supply. Each computer will interface to the INMARSAT terminal through the FAX/modem using modem control (communications) software. The computers will also be equipped with an ethernet adapter to connect to the existing site local area network (LAN) using the LANtastic network operating system. Additionally, the computer at the regional center will have high–speed (DS0, X.25) capabilities using the bridge/router and the high–speed data option on the INMARSAT terminal.

OPERATIONAL AND SUPPORT REQUIREMENTS

Operational considerations fall into two categories: security and operational procedures. Physical security is required at each site. Physical separation of the terminal into two fixed sections will aid in security, but access to the external antenna, the terminal electronics unit, and the dedicated computer must be restricted to authorized users. Operational procedures will be established to limit the number of people with access to the system, to require the use of a password to log onto the computer, and to set up the system in a manner that inhibits use in an undesired fashion (i.e. – use of voice capability from a data only installation).

Each site will require two or three people who are trained in routine operation of the system and simple troubleshooting procedures. Moreover, the ARC will require two to three people who are trained in operations, maintenance, and repair of the equipment. Training of ARC personnel will occur at the vendor's facility, and training of NAC personnel will occur at the NAC.

The skills required at the ARC will encompass two areas: operators and engineers. Operators will require training and expertise in using the equipment and in operational procedures. Engineers will require both knowledge of operations and equipment maintenance. A typical scenario at the ARC will have one operator per shift, with a backup person available as an alternate operator, and one engineer (possibly only on–call) per shift. The skills at the NAC's will be somewhat different. The operators will be trained in some of the routine equipment maintenance procedures as well as training to interface with ARC engineers for troubleshooting.

Since AGRHYMET is primarily supported by donor contributions, low recurring costs are important. An analysis of typical operating expenses is shown in table 2. The figures listed are based on nominal file sizes for each country and a 9.6 KBPS transfer rate.

CONCLUSIONS

USAID has funding to install a system of INMARSAT terminals to connect the ARC and the NAC's. The procurement process is underway, and initial operating capability is planned to support the 1993 growing season. Further uses of the system include remote diagnostics of the ARC computer systems from the EDC using the high–speed data link and support of field work using land–mobile terminals. Disaster relief efforts may also use land–mobile terminals as part of the AGRHYMET network.

Table 2. Recurring Cost Analysis

Country	NDVI File MB	Transfer Time min	Weather Data MB	Transfer Time min	Sea Surface Temp MB	Transfer Time min
Burkina Faso	0.40	5.56	0.20	2.78	n/a	n/a
Cape Verde	n/a	n/a	0.20	2.78	1.20	16.67
Chad	1.30	18.06	0.20	2.78	n/a	n/a
Gambia	0.03	0.42	0.20	2.78	1.20	16.67
Guinea Bissau	0.70	9.72	0.20	2.78	1.20	16.67
Mali	1.70	23.61	0.20	2.78	n/a	n/a
Mauritania	1.10	15.28	0.20	2.78	1.20	16.67
Niger	1.30	n/a	0.20	n/a	n/a	n/a
Senegal	0.20	2.78	0.20	2.78	1.20	16.67
Totals	6.73	75.42	1.80	22.22	6.00	83.34
Cost at $10/min		1508.45		444.48		1666.80
Cost at $6/min		905.07		266.69		1000.08

Total cost per decade (NDVI, weather, sea temp) =	3619.73	($10/min)
	2171.84	($6/min)
Total cost per decade (NDVI, weather only) =	1952.93	($10/min)
	1171.76	($6/min)
Total annual cost (13 decades, NDVI, weather data only) =	25388.14	($10/min)
	15232.89	($6/min)
Total annual cost (13 decades, NDVI, weather, sea temp) =	47056.54	($10/min)
	28233.93	($6/min)

Notes -

All links are double bounce ($10/min or $6/min in each direction)
Times are for compressed files (approximately 50% size reduction) at 9.6 KBPS
Sea surface temperature map is 8 bit pixels, 640x480 (VGA) resolution
Sea surface temperature maps are distributed weekly (twice per decade)
Sea surface temperature maps are shown as candidate new product

ACKNOWLEDGMENTS

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REFERENCES

[1] Niamey Field Office, *The Center Scene*, Spring 1992, EROS Data Center, Sioux Falls, SD 57198, p. 4–6.

[2] Eidenshink, J. C., 1992: The 1990 Conterminus US AVHRR Data Set, *Photogrammetric Engineering and Remote Sensing*, Volume 58, Number 6, June 1992, 809–813.