16.7 THE TRANSITION TO OPERATIONS OF NOAA'S LOW-RATE INFORMATION TRANSMISSION (LRIT) SYSTEM

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1. INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) Low-Rate Information Transmission (LRIT) System began its transition to operations in August 2003 and will complete the transition by the end of 2005. The LRIT processing system was developed and implemented under Computer Sciences Corporation's (CSC) Central Satellite Data Processing contract to NOAA's National Environmental Satellite Data and Information Service (NOAA/NESDIS), to provide a replacement for the current Weather Facsimile (WEFAX) Processing System.

The transition to operations is being done in two phases for each of the satellites in the Geostationary Operational Environmental Satellite (GOES) constellation (GOES-EAST and GOES-WEST). The first phase is a timesharing, alternate transmission mode with WEFAX. The second phase is full replacement of WEFAX. WEFAX is an analog communications transmission service. LRIT is a digital communications transmission service. The transition from current WEFAX service to total LRIT service is planned to occur over a two-year period for the GOES constellation. Parallel service, albeit in timesharing mode, is to facilitate the ease of transition to LRIT for existing WEFAX users.

2. OVERVIEW OF LRIT

The digital LRIT is an international standard for data transmission that was developed by the Coordination Group for Meteorological Satellites (CGMS) in response to the recommendation for digital meteorological satellite broadcasts. The CGMS Global Specification (Reference 1) provides the standard that is supported by all operational geostationary meteorological satellites to be flown by the United States, European agencies, Japan, China, and Russia. NOAA and other world meteorological agencies have developed subsequent system specifications, designs, and implementations of their specific LRIT systems. This paper along with References 2 and 3 provides details of NOAA's LRIT system. More information on NOAA's LRIT system can be found at its web site, http://noaasis.noaa.gov/LRIT/.

The LRIT system will provide digital data, via a broadcast service, through the GOES satellites. Digital data will include equivalent products transmitted through the WEFAX service but will not be limited to them. The main sources of data for LRIT are the GOES satellites operated by NOAA. The GOES system consists of two operational platforms, GOES-East and GOES-West (respectively GOES-12, and GOES-10), and various satellites currently in orbit and in either standby or storage mode. Other sources of LRIT data include:

- GOES-9 data in replacement of Geostationary Meteorological Satellite (GMS)-5
- Global Telecommunications System (GTS)-formatted data from the National Weather Service (NWS)
- Alphanumeric (text) messages
- GOES Data Collection System (DCS)

The LRIT system, with a digital format, provides NOAA the opportunity to transmit more data, of various types, and with more flexibility than the WEFAX system allows.

3. WEFAX vs. LRIT

Using the LRIT service has several benefits over that of the WEFAX service. The LRIT system, for instance, uses digital data rather than analog data. The benefits include how much data can be transmitted, how consistent the data stays in transmission, and what type of data the signal can carry. For the same amount of bandwidth, much

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more information can be packed into a digital signal than an analog signal and maintain a more accurate value per pixel than that produced using an analog signal. Figures 1, 2, and 3 demonstrate the value added in using digital data over analog data. Figure 1 is a GOES-East full disk image as viewed on the LRIT user station. Figure 2 is the WEFAX product for the same full disk image. Comparing figures 1 and 2 doesn't show much difference visually, but in actuality the LRIT image is at 4km resolution and the WEFAX image is at 16km resolution. Figure 3 demonstrates one of the benefits of digital data. It shows a zoomed in portion of the full disk image. With the WEFAX image, figure 2, what you see is what you get. With the LRIT data, one can take advantage of the higher resolution when using the data.

Although digital representations approximate analog events, they are useful because they are relatively easy to store and can be manipulated electronically. Manipulation of the data can lead to improvements in the latency of the data to the user community, a feature not available with the WEFAX service. This reduced latency is realized in two ways. First, WEFAX products are generated at NESDIS's Information Processing Division (IPD) only after the GOES VARiable (GVAR) length data have been fully processed by the Front-End Processor (FEP). This processing can take up to 26 minutes for a full-disk product to be ingested. The LRIT system has been designed so that LRIT-segmented products can be generated and transmitted even as the GVAR data is still being ingested and processed.

These LRIT segments can be transmitted and received prior to completion of the ingested GVAR data at IPD. Secondly, digital data lends itself to compression. LRIT image data can be compressed, in accordance with the CGMS LRIT/HRIT Global Specifications. Compression has a dual purpose in the LRIT system. Not only does compression allow data to be transmitted to the user more quickly, it also allows for larger volume products to be included in the LRIT product suite that could not otherwise be included in the WEFAX service.

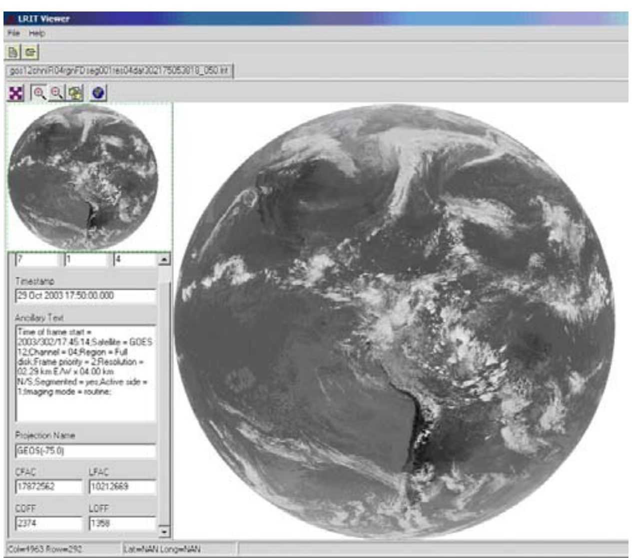

Figure 1. GOES-East Full Disk Image Viewed Using LRIT

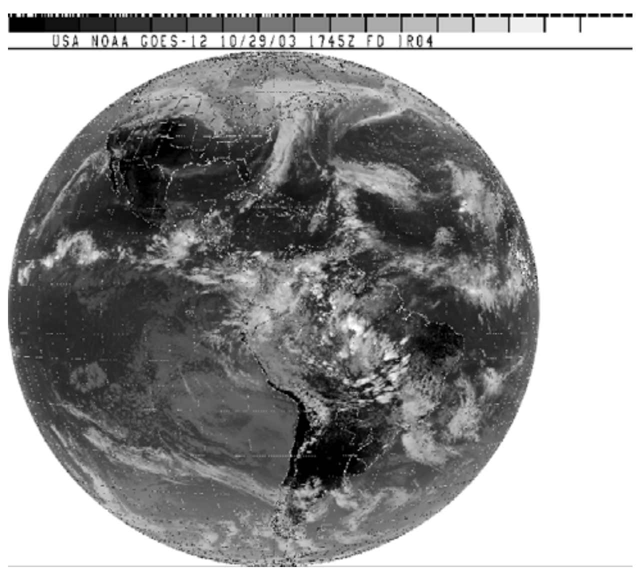

Figure 2. GOES-East WEFAX Full Disk Image

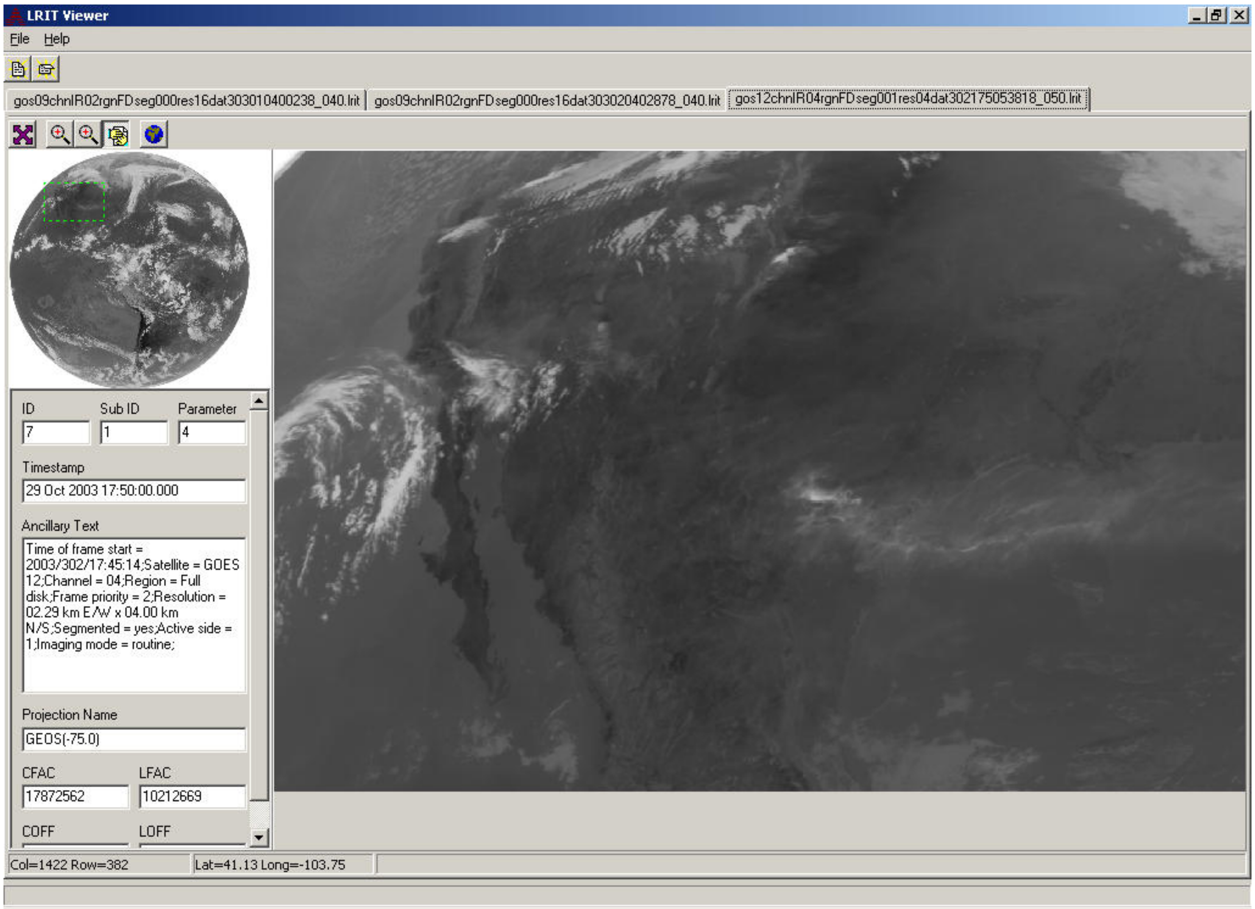

Figure 3. Zoomed In Portion of the LRIT Full Disk Image.

Table 1 compares the daily volume of data for both WEFAX and LRIT.

Table 1. Volume Comparison

Amount of WEFAX Data in 24 hours		330 million bytes per day
Amount of LRIT Data in the current timeshare mode		31.6 million bytes per 29 minute timeshare period
Amount of LRIT Data possible in 24 hours		1.5 billion bytes per day

In Reference 3, both the GOES-East and GOES-West WEFAX volumes are computed based on product types. For the LRIT volumes in Table 1, the byte counts received at the user terminal were recorded for several 29-minute periods and averaged. It should be noted that the byte counts for LRIT consist of a count of bytes before decompression of the data. This yields more product data bytes after decompression.

Additionally, the manipulation of the digital data allows for LRIT products to be encrypted, as specified in the CGMS Global Specification. NOAA has no current plans to encrypt any of the LRIT data.

Another benefit of LRIT over WEFAX is the flexibility gained by not transmitting according to a very rigid schedule. Figure 4 is an excerpt of the GOES-East WEFAX schedule before timesharing.

In studying the WEFAX schedule presented, it can be seen that the GOES-8 data that was ingested beginning at 20:45 was not transmitted to the users until beginning at 22:30; that is an hour and a half after receipt began. The last of the 20:45 data was not transmitted until 23:14, which is almost 2 and1/2 hours after receipt. With LRIT, since the data is processed in near-real-time and not relying on a schedule, the 20:45 data, which consisted of three full-disk images, one each visible, water vapor, and infrared, were processed and transmitted to the users beginning at 20:55 and completed at approximately 21:20. With LRIT, the users have the earliest data at least an hour sooner and almost 2 hours sooner for the last data.

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20:40 24HR 300MB PROG SHL1 W058
20:45 24HR 300MB PROG APT4 W059
20:50 24HR 200MB PROG SHL1 W060
20:55 24HR 200MB PROG APT4 WO61
21:00 24HR 500MB PROG SHL1 W062
21:05 24HR 500MB PROG APT4 W063
21:10 GOES-8 1945Z NH IR
21:14 GOES-8 1945Z NH VS
21:18 NOAA-14 DIR MER 070E-000E W021
21:22 MET-7 2100Z D7 IR
21:26 MET-7 2100Z D8 IR
21:30 MET-7 2130Z D2 IR
21:35 24HR 850MB PROG PA33 W050
21:40 24HR 850MB PROG
21:45 24HR 700MB PROG PA33 W052
21:50 24HR 700MB PROG HON1 W053
21:55 00HR MSLP 1-500 THK PN26 W150
22:00 00HR MSLP 1-500 THK
22:05 24HR MSLP 1-500 THK PN26 W152
22:10 24HR MSLP 1-500 THK NT21 W153
22:15 48HR MSLP 1-500 THK PN26 W154
22:20 48HR MSLP 1-500 THK NT21 W155
22:24 open space
22:30 GOES-8 2045Z NH IR
22:34 GOES-8 2045Z NE IR
22:38 GOES-8 2045Z SE IR
22:42 GOES-8 2045Z NW IR
22:46 GOES-8 2045Z SW IR
22:50 GOES-8 2045Z 4KM US IR
22:54 GOES-8 2045Z 16KM FD IR
22:58 GOES-8 2045Z NH VS
23:02 GOES-8 2045Z NE VS
23:06 GOES-8 2045Z SE VS
23:10 GOES-8 2045Z NW VS
23:14 GOES-8 2045Z SW VS
23:20 48HR MSLP 1-500 THK
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Figure 4. Excerpt From GOES-East WEFAX Schedule

Unlike WEFAX, which is directly tied to a schedule, LRIT has the ability to prioritize data as it enters the processing system, enabling data that is deemed higher in priority to supersede other data being processed. LRIT allows data to be transmitted to the user community without waiting for its slot in a rigid schedule. It adds flexibility to the processing and transmission of LRIT products.

4. CURRENT LRIT CAPABILITIES

The processing of data and the subsequent transmission of the LRIT products was designed to be more robust and flexible than the current WEFAX service. This flexibility extends to the ingestors, the processors, and the transmission and reception portions of the system.

Able to process GVAR data, the LRIT system ingestors are configurable. These ingestors provide the operator the ability to specify the number of segments each product will be divided into for processing and transmission. They also permit the configuration of such parameters as the region of coverage, the data resolution, and the channel(s), to be processed. Additionally, Rapid Scan Operations (RSO) data are ingested and can be made available to the LRIT Product Processor (LPP) system. The flexibility of the ingestors enhances the overall robustness of the LRIT system.

The CGMS LRIT Global Specification defines a reference model with multiple layers. The model is generally consistent with both the Consultative Committee for Space Data System (CCSDS) and the International Standards Organization's (ISO) Open Systems Interconnect (OSI) reference model. The LRIT system is essentially a unidirectional flow of data from a transmission side (uplink) to a reception side (downlink). The model used for LRIT implementation includes seven layers consisting of:

1. Application Layer
2. Presentation Layer
3. Session Layer
4. Transport Layer
5. Network Layer
6. Data Link Layer
7. Physical Layer

On the transmission side, data is processed into LRIT files in the Application and Presentation Layers, which correspond to the LRIT Product Processor. Performed in layers 3 through 7, LRIT Communications Processing is concerned with sending LRIT files from the transmission side to the reception side.

The LRIT Product Processor (LPP) system adds flexibility and robustness to the LRIT system. A configurable system, the LPP's primary purpose is to create LRIT product files from various input sources, such as the GOES data from the ingestors. It is in the LPP that product priority is determined and assigned. Not only is the LRIT data assigned a transmission priority, it is also given a processing priority. The distinction between the two relates to where the priorities are implemented. The processing priority's significance is in the LPP; whereas the transmission priority is significant in the communications processing. Processing priority represents the amount of central processing unit (CPU) a given process receives relative to the other processes concurrently being performed. Transmission priority represents the priority an LRIT product file receives in the communications processing system. This priority allows for higher priority data to supersede lower priority data currently being transmitted. Such priority processing permits data that is deemed more urgent the opportunity to be transmitted quickly, thus reducing the latency for higher priority data.

The configurable design of the LPP lends itself to setting other features that improve the overall performance of the LRIT system. One of the most important of these parameters is the compression flag. The compression flag, currently applicable only to image data, gives the flexibility to perform compression of data prior to transmission. There are three compression options:

- No compression
- Lossless compression
- Lossy compression

Currently, the NOAA LRIT implementation of lossless compression is the Rice compression algorithm and is implemented in the Transport Layer. Lossy compression currently employs Joint Photographic Experts Group (JPEG) compression and is implemented in the Session Layer. The benefit of Rice compression in the transport layer is that the compression is performed on packets rather than on a file. The significance of this is realized in the reduced risk of losing data in transmission. File compression risks losing the whole file if any data is lost or corrupted in transmission. The decompression software on the reception side does not have the necessary information to reconstitute the file. Packet compression, however, limits loss or corruption of transmitted data to the affected packet rather than losing the whole file. The reception software can reconstitute the file with missing data for the lost or corrupted packets.

The current implementation of the LRIT broadcast service is a timesharing mode with the current WEFAX service. To alternate between the two transmission windows, a switch located at Wallops, Virginia has been employed. A configurable scheduler at IPD controls the switch. In conjunction with the initial operational capabilities (IOC) of LRIT, is the LRIT receiver software. NOAA is making available a limited amount of user station software that provides basic receiver functionality and product display capabilities. This source code can be found at: http://noaasis.noaa.gov/LRIT/ and is freely available to the user community.

5. TESTING

Testing the LRIT system, as compared to the WEFAX service, was very favorable. The results demonstrated a reduction in product latency, an increase in product volume, and a broadening of product content. Table 2 reflects the improvements in product latency. For an actual GOES full disk image, the data shows that the user received all of the data within 32 minutes of ingest (rightmost column). However, the first segment (1/5 of the full disk) was received within 10 minutes of ingest. With LRIT, the user is getting the data sooner.

Table 2: Sample Product Latency

Infrared, 4KM, Full Disk at 20hrs:45min			
Segment	Begin Processing Time	Time of Receipt at the user station	Time to User from Start of Ingest of Data
1	20:53:06	20:54:57	0:09:57
2	20:58:22	21:01:05	0:16:05
3	21:03:41	21:06:37	0:21:37
4	21:08:47	21:12:18	0:27:18
5	21:14:01	21:16:08	0:31:08

In Table 2, there is an unaccounted-for time period between the beginning of a segment processing time and the time of receipt of the previous segment at the user station. This would be considered dead time, if LRIT were processing only one set of input at a time. In general however, LRIT is processing other products such as, other GOES, DCS, etc. In this case, LRIT was ingesting three full-disk products and within that 32 minutes had transmitted all three products to the users.

Latency was reduced substantially, as compared to WEFAX. This reduction in latency permits the LRIT system to be more near-real-time than was possible with the WEFAX service.

The increase in product volume, as shown in Table 1, is realized by using lossless compression. An additional increase in product volume can be gained by using lossy compression. The gain in product volume, using lossy compression, is offset by a loss in data accuracy. This loss in data accuracy can be weighed against the increase in product volume to determine whether the exchange is detrimental to the products being transmitted. Initial results indicate that lossy compression is useful for some products but not worth the loss in accuracy for other products. Another benefit gained through the LRIT system is an increase in the product content.

System integration testing began in April 2003 with the installation of hardware at NOAA's Wallops Command and Data Acquisition (CDA) facility. Successful integration testing of NOAA's LRIT system included transmission of data to and from the GOES-East satellite and ensured the availability of test data files in May of 2003 to all users on NOAA's LRIT web site.

The contents of the data files published for review and testing by the LRIT user community are as follows:

- 3 GMS
- 2 GOES-10 full disk (one segment missing)
- 1 GOES-10 northern hemisphere
- 1 GOES-10 southern hemisphere
- 1 GOES-10 United States
- 1 GOES-12 full disk
- 1 GOES-12 northern hemisphere
- 1 GOES-12 southern hemisphere
- 1 GOES-12 United States
- 1 Alphanumeric message

More specifics regarding these test data sets can be found at NOAA's web site http://noaasis.noaa.gov/LRIT/ .

On 21 August 2003, NOAA began transmitting LRIT test data during two daily "vacant" time slots in the GOES East WEFAX schedule. The LRIT test data was transmitted Monday through Friday, excluding U.S. Holidays, during these vacant times throughout the months of August and September. The first daily test transmission period was from 16:50 to 17:06 UTC, and the second daily test transmission period was from 17:50 to 17:58 UTC. A one-minute buffer at the start and end times was used to avoid interference with WEFAX.

All of the testing concluded successfully.

6. TRANSITION

The LRIT/WEFAX timeshare became active on GOES-East at 0000Z on 7 October 2003, when NOAA began full timeshare operations of WEFAX and LRIT on the WEFAX transponder of GOES-East. Every hour there will be 31 minutes of WEFAX, starting at xx:14, and 29 minutes of LRIT, starting at xx:45 (see Figure 5).

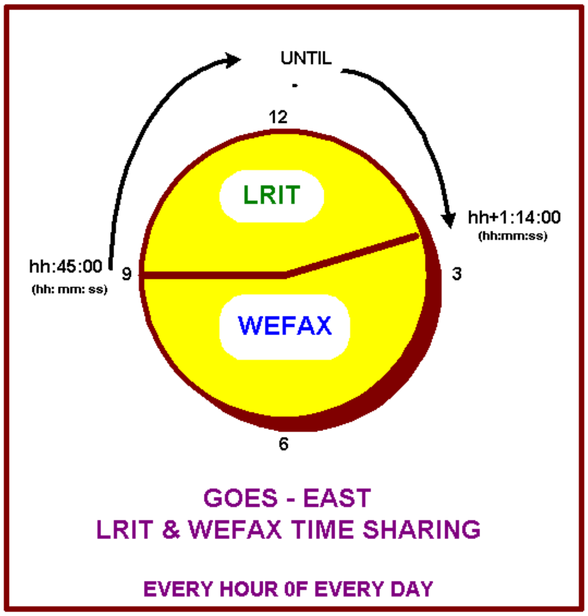

Figure 5. GOES-East Timesharing

This transition phase will last approximately 12 months, at which point WEFAX will be eliminated from the GOES-East and LRIT will operate continuously. Figure 6 presents the timeline for transition.

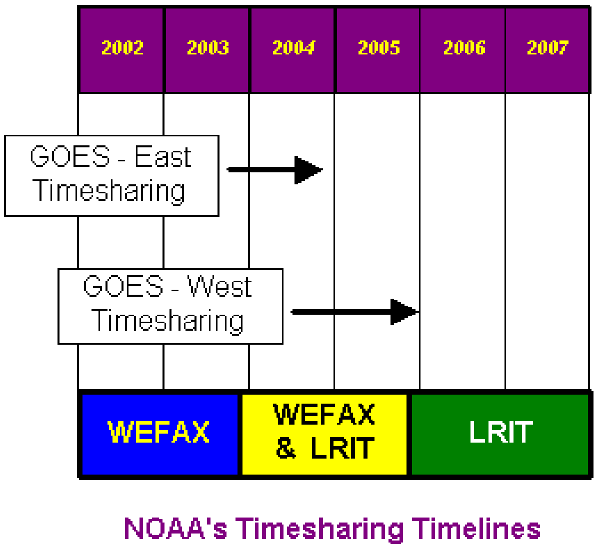

Figure 6. LRIT & WEFAX Timesharing

The transition on the GOES-West satellite should commence with timesharing the 2nd quarter of 2004. The plan is to perform timesharing similar to what is currently being done for GOES-East.

Full LRIT only (no WEFAX) is planned to begin late 2005.

7. FUTURE PLANS (SUMMARY)

Now that NOAA's LRIT is operating regularly in the timesharing mode for the GOES-East satellite, the immediate plans include completing the transition on GOES-East and beginning the transition on GOES-West in 2004. Ultimately, WEFAX will be replaced with LRIT by the end of 2005.

Other items being considered for future implementation include expanding the product suite, adding higher resolution imagery (e.g. 1km), adding other compression algorithms (e.g. JPEG2000, zip), improving navigation information, and adding a web server for LRIT files. Though these are some of the ideas for future enhancements, by no means is LRIT limited to just these. As LRIT becomes utilized by the user community and matures, so shall the capabilities offered.

8. REFERENCES

1. CGMS LRIT/HRIT Global Specifications, Doc. No. CGMS 03, 1999.

2. Frank Eng and C. A. Vance, *National Oceanic and Atmospheric Administration (NOAA) Implementation of Low-Rate Information Transmission (LRIT) Services*, Proceedings of the 18th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, January 2002;

3. Frank Eng, R. Luczak, and C. A. Vance, *National Oceanic and Atmospheric Administration (NOAA) Implementation of Low-Rate Information Transmission (LRIT) Product Projections*, Proceedings of the 19th International Conference on Interactive Information and Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, February 2003