Geostationary Operational Environmental Satellite (GOES)

GOES-R Series

Interface Requirements Document (IRD)

Space Segment (SS)
To
Search and Rescue (SAR) Service

Draft

June 3, 2003

National Aeronautics and Space Administration

Goddard Space Flight Center
Greenbelt, Maryland

To verify the correct version of this document, please contact the GOES R Series Requirements Management Office on 301-286-7898

Table of Contents

1 Introduction

The Geostationary Operational Environmental Satellite Series R (GOES-R) System will provide an expanded capability series of spacecraft to follow those developed and launched under the GOES N-Q Program. The expanded capabilities will follow from anticipated developments of the payload instrument suites as well as the several ancillary services included in the program mission. Six GOES-R Mission Segments interface and function to support the total GOES-R mission. They are:

- **Space Segment (SS)**
- Launch Support Segment (LSS)
- Ground Located - Command, Control, and Communications Segment (GL-C3S)
- Product Generation and Distribution Segment (PGDS)
- User Interface Segment (UIS)
- Archive and Access Segment (AAS)
- As part of the Space Segment (SS), the GOES-R will support several NOAA auxiliary services:
- GOES Rebroadcast (GRB) Service
- Low Rate Information Transmission (LRIT) Service
- Emergency Managers Weather Information Network (EMWIN) Service
- Data Collection System (DCS)
- **Search and Rescue (SAR) Service**

1.1 Purpose

The purpose of this document is to describe and specify the functional and performance interface requirements for the communication links between the GOES-R Space Segment (SS) and the Search and Rescue (SAR) Service.
This document it also intended to provide a basis for the subsequent development of a SS-SAR Interface Control Document (ICD).

1.2 Scope

The interface addressed in this document supports the exchange of data between the SS and the SAR ground segments. The SAR transponder in the GOES-R Series spacecraft (i.e., a component of the SS) performs a direct frequency translation of the uplink 406 MHz SAR RF band to a downlink L-Band band. Only those parameters which are necessary to specify the interface requirements will be referenced here; additional satellite transponder specifications will be contained in a satellite performance specification. This IRD therefore:

- Identifies required RF links between the SS and the SAR ground segments
- Establishes functional and performance requirements related to these links

It is worth noting that the architecture for this frequency translation transponder is changed from the configuration on the GOES-N Series wherein a phase remodulation of the full 406 MHz uplink band onto a downlink L-Band carrier is implemented. This has implications for the SAR Local User Terminals (LUTs) discussed below.

1.3 Document Overview

This document contains six Sections and two Appendices.
Section 1 explains the purpose and scope of the IRD. It contains a list of applicable and reference documents relevant to the interface.
Section 2 describes the SAR system functional elements that must be supported by the subject interfaces. Section 3 contains describes the characteristics of the SAR 406 MHz Distress Beacons relevant to the interface with the GOES-R Space Segment. Section 4 describes the relevant characteristics of the Local User Terminals (LUTs).
Section 5 provides the functional and performance requirements that must be met by the SS to support the link interfaces.
Section 6 specifies the overall link performance that must be met under specified assumptions.
Section 7 lists "To Be Determined" (TBD) and "To Be Reviewed" (TBR) parameters and issues in the IRD.
Section 8 lists abbreviations and acronyms used in the IRD.

1.4 Applicable Documents

The following documents [1] through [6] contain information about the SAR Service and are applicable to the extent specified herein. They are available on the Internet at http://www.cospas-sarsat.org
In the event of conflict between this IRD and documents [1] through [6], this document shall take precedence.
[1] Cospas-Sarsat, C/S G.003, Introduction to the Cospas-Sarsat System, Issue 5 - Revision 1, October 1999
[2] Cospas-Sarsat, C/S T.001, Specification for Cospas-Sarsat 406 MHz Distress Beacons, Issue 3- Revision 3, with Corrigendum 1, October 1999
[3] Cospas-Sarsat, C/S T.009, Cospas-Sarsat GEOLUT Performance Specification and Design Guidelines, Issue 1 - Revision 1, October 1999
[4] Cospas-Sarsat, C/S T.011, Description of the 406 MHz Payloads Used in the Cospas-Sarsat GEOSAR System, Issue 1 - Revision 3, October 2001
[5] Cospas-Sarsat, C/S T.013, Cospas-Sarsat Geosar Space Segement Commissioning Standard, Issue 1, October 2001
Currently one additional applicable Cospas-Sarsat document exists in draft form only. Relevant information from this document has been utilized herein, but it is advised that prior to system design the most recently released version of [6] be consulted:
[6] Cospas-Sarsat, C/S T.012, Cospas-Sarsat 406 MHz Frequency Management Plan, Issue 1 - Draft 5, May 2001.

2 Search and Rescue (SAR) Service and Interface Description

2.1 General Description

The GOES support to the Search and Rescue (SAR) service is provided by GOES satellites located at 75º and 137º [TBR] W. Longitude. Each satellite employs an earth coverage antenna for reception of the uplink SAR UHF beacon signals and another earth coverage antenna to provide a downlink L-Band relay to the supporting ground terminals. Both the beacons and the LUTs may be anywhere in the earth coverage area of the satellite out to a design minimum elevation angle of 5º.

The SAR subsystem onboard each GOES satellite is a dedicated transponder that receives UHF distress signals broadcast by

- Emergency Locator Transmitters (ELTs) carried on aircraft,
- Emergency Position Indicating Radio Beacons (EPIRBs) aboard marine vessels, and
- Personal Locator Beacons (PLB) used in land-based applications.

The beacons are channelized in an 80 kHz bandwidth as described in Section 3.2. Within the GOES SS, this entire uplink SAR bandwidth is frequency translated to L-Band and downlinked to a Search and Rescue Satellite-Aided Tracking (SARSAT) ground terminal. These ground terminals are referred to as Geostationary Earth Orbit Local User Terminals (GEOLUTs). In this document, where there is no possibility of ambiguity with Low Earth Orbit Local User Terminals (LEOLUTs), they will be referred to simply as Local User Terminals (LUTs).

Figure 2-1 shows the SS-to-SAR interface. The required connectivity through the GOES-R Series satellites is shown in Figure 2-2. Not shown in this figure are other links that support downlinking of the instrument data (Sensor Data or SD) and the transponder support to the other ancillary services.

Figure 2-1: SS-to-SAR Interface Diagram

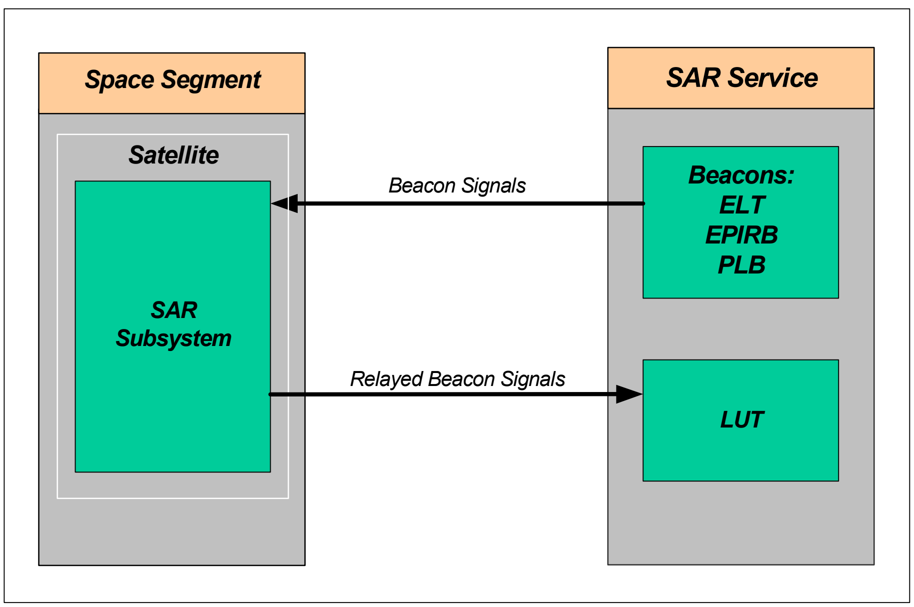
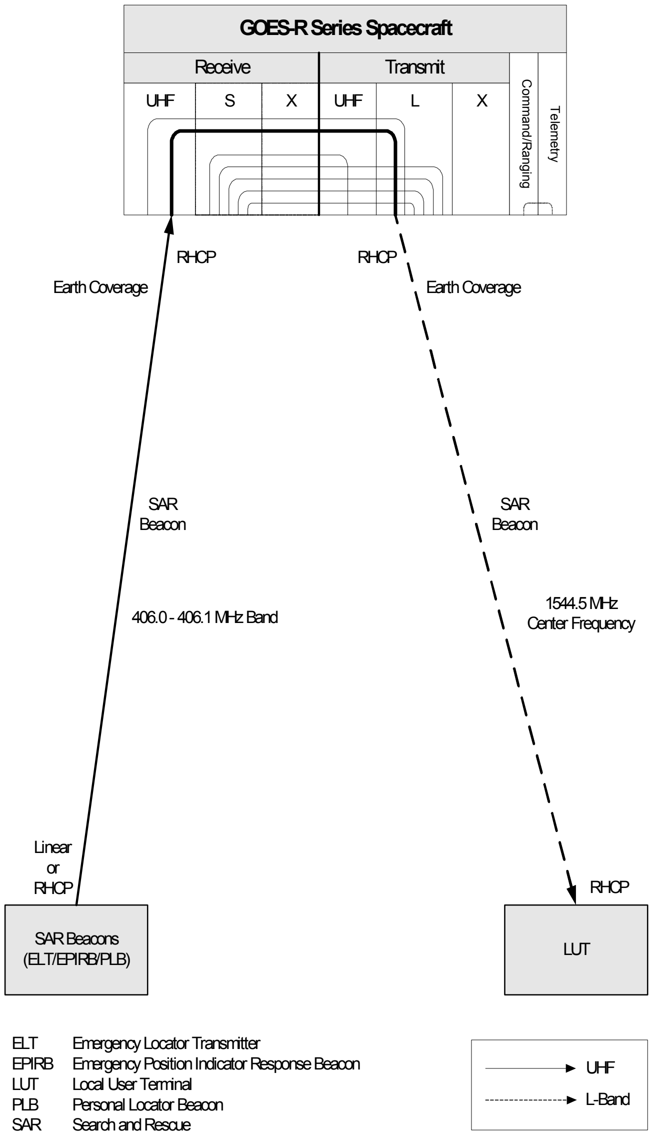


Figure 2-2: SAR Connectivity through GOES-R Series Satellites



3 Distress Beacon Requirements

3.1 Introduction and Functional Elements

As indicated in Section 2.1, the SAR 406 MHz Distress Beacons include three implementations: ELT, EPIRB, and PLT. Each of these includes a Digital Message Generator, a Modulator, and a 406 MHz transmitter. Only those elements necessary for specifying the SS-to-SAR interface will be addressed here. Additional information is available in the applicable documents (Section 1.4).

3.2 Frequency Channelization

The beacon uplink frequencies are one of 19 channels, each of 3 kHz bandwidth. The channel center frequencies are shown in Table 3-1.

Table 3-1: SAR Beacon Frequency Channelization

Search and Rescue - Beacon Channel Assignments			
Channel	Frequency (MHz)	Accuracy (kHz)	Comments
1	406.022	± 1	System Beacons
2	406.025	± 2	Beacons sold from 1982-2002
3	406.028	± 1	Open in 2000
4	406.031		Future assignments. These may be non-sequentially allocated and may use the whole range.
5	406.034		
6	406.037		
7	406.040		
8	406.043		
9	406.046		
10	406.049		
11	406.052		
12	406.055		
13	406.058		
14	406.061		
15	406.064		
16	406.067		
17	406.070		
18	406.073		
19	406.076		

3.3 Frequency Accuracy and Long-Term Stability

The initial frequency accuracy for beacons manufactured prior to January 1, 2000 is specified as ± 2 kHz. From January 1, 2000, this has been tightened to ± 1 kHz. The long-term stability is specified as ± 5 kHz over 5 years for beacons manufactured prior to January 1, 2000 and +2 kHz/ -5 kHz over 5 years from January 1, 2000.

3.4 Short-Term Frequency Stability

The short-term frequency stability is specified as ≤ 2 parts in 10^9 over 100 ms.

3.5 Beacon Power and EIRP

Beacon EIRP is specified as 5 W ± 2 dB (35 - 39 dBm) at the antenna input. The antenna gain is specified as -3 dBi to +4 dBi over 90% of a hemispherical pattern defined for elevation angles from 5° to 60°. For link budget purposes the EIRP **shall** be considered to be 32 dBmi worst case [TBR], with an additional 2 dB “antenna orientation loss”, while recognizing that absolute worst case scenarios could result in worse values.

3.6 Beacon Polarization

Beacon transmit polarization is specified as either linear or RHCP. For link budget calculations, a polarization mismatch corresponding to a linearly polarized beacon antenna and a RHCP satellite receive antenna (see Section 5.1.6) **shall** be assumed.

3.7 Beacon Modulation

3.7.1 Data Rate

The transmission data rate is 400 bits/s.

3.7.2 Data Encoding

The data is encoded in a biphase L format. This format is described in reference document [2].

3.7.3 Modulation

The modulation is linear phase modulation with a positive and negative peak deviation of 1.1 ± 0.1 radians, referenced to an unmodulated carrier.

4 Local User Terminal (LUT) Requirements

The LUTs are L-Band receive-only terminals.

4.1 Receive Frequency Band

The receive center frequency is 1544.500 MHz. The receive bandwidth is approximately 100 kHz to match the downlink translation bandwidth. The allocated bandwidth for this service is wider, 1 MHz centered at 1544.500 MHz.

4.2 G/T

The LUT G/T **shall** be a minimum of 11 dB/K. This includes any antenna mispointing. Tracking is not required.

4.3 Receive Polarization

The antenna polarization **shall** be RHCP with a maximum axial ratio of 2 dB.

4.4 Demodulation

The LUT **shall** be capable of phase demodulation of the received beacons. Baseband processing of the received data signal is described in reference document [2].

5 Space Segment (SS) Requirements

The Space Segment (SS) requirements consist of receiving the uplink 100 kHz wide 406 MHz beacon frequency band, directly frequency translating to an equivalent bandwidth in L-Band, amplifying, and transmitting this signal to the ground station LUT.

5.1 Beacon-to-SS UpLink Interface

5.1.1 Frequency Band

The uplink frequency band is a nominal 100 kHz bandwidth centered on 406.050 MHz.

5.1.2 Nominal Signal Level

As a guideline, for a 5 W beacon located at a 45° elevation angle to the satellite, with a 4.1 dB polarization mismatch loss, the signal level at the spacecraft antenna (before antenna gain) is approximately -173.1 dBm [TBR].

5.1.3 Satellite Receive System Noise Temperature

The system noise temperature referenced to the receiver input **shall** not exceed 359 K.

5.1.4 Satellite Receive G/T

The satellite receive G/T **shall** be a minimum of -16 dB/K at edge of coverage [TBR].

5.1.5 Satellite Receive Antenna Coverage

The satellite beacon receive antenna coverage **shall** be earth coverage with minimum elevation angle of 5° [TBR].

5.1.6 Satellite Receive Antenna Polarization

The satellite beacon receive antenna polarization **shall** be RHCP with an axial ratio not to exceed 3 dB over the specified coverage area [TBR].

5.2 SS-to-LUT Downlink Interface

5.2.1 Frequency Band

The downlink frequency band **shall** be centered on 1544.500 MHz.
The required bandwidth **shall** be 100 kHz.

5.2.2 Satellite EIRP

The downlink EIRP **shall** be a minimum of 15.0 dBW (45.0 dBm) [TBR] over the required coverage area.

5.2.3 atellite Transmit Antenna Coverage

The downlink satellite beacon transmit antenna coverage **shall** be earth coverage to a minimum elevation angle of 5º [TBR].

5.2.4 Satellite Transmit Antenna Polarization

The downlink satellite beacon transmit antenna polarization **shall** be RHCP with a maximum axial ratio of 3 dB [TBR].

6 Link Performance Specification

Based on the assumed link parameters of Section 6.1, the link performance shall meet the performance criteria of Sections 6.2 and 6.3. Performance is specified for the combined up and downlinks, i.e., for the full path between beacon and LUT.

6.1 Assumed Link Parameters

The following conditions shall be assumed in the calculation of expected link performance.

1. The worst case effective beacon EIRP of 30 dB [TBR] shall be assumed. This follows from a beacon power output of 35 dBm (i.e., nominal 37 dBm - 2 dB), followed by a worst case antenna gain (-3 dBi), followed by an additional 2 dB loss for antenna orientation.
2. Propagation impairments of 0.2 dB [TBR] on the uplink (406 MHz) and 0.5 dB [TBR] on the downlink shall be assumed.
3. Elevation angles at both the beacon and the LUT shall be assumed to be the worst case value of 5º [TBR].
4. Worst case polarization mismatches on the uplink and downlink **shall** be assumed. Effects of non-ideal axial ratios **shall** be included.
5. Interference accesses **shall** be assumed to be small and no specific entry is required.
6. At the LUT receiver, the required E_b/N_0 **shall** be 4.5 dB before applying (a) an implementation loss of 2 dB, (b) a modulation loss due to non-orthogonal PSK of 1 dB, (c) a BCH coding gain of 2 dB and (d) an integration gain (from multiple messages) of 6 dB.

6.2 Link Availability

The link calculations **shall** demonstrate link closure, i.e., positive link margin, under the assumptions specified in Section 6.1. Due to the benign propagation environment at these frequencies, end-to-end link availability is expected to be 99.9% minimum for the worst month [TBR].

6.3 Link Bit Error Rate

The end-to-end link bit error rate (BER) shall be $1 \cdot 10^{-5}$ [TBR] or better under the worst case assumptions of Section 6.1. As indicated in Section 6.1 (5), this results from a required E_b/N_0 of 4.5 dB with a net 5 dB of receiver processing gain for a net required effective E_b/N_0 of 9.5 dB.

7 TBR/TBD Listing

Number (SS/SAR)	Description	Resolution Plan	Date
TBR/TBD1	§5.1.2, nominal signal level	Analysis/Review by CWG	3 Jun 03
TBR/TBD2	§5.1.4, satellite receive G/T	Analysis/Review by CWG	3 Jun 03
TBR/TBD3	§5.1.5, satellite receive antenna minimum elevation angle	Analysis/Review by CWG	3 Jun 03
TBR/TBD4	§5.1.6, satellite receive antenna axial ratio	Analysis/Review by CWG	3 Jun 03
TBR/TBD5	§5.2.2, satellite EIRP	Analysis/Review by CWG	3 Jun 03
TBR/TBD6	§5.2.3, satellite transmit antenna minimum elevation angle	Analysis/Review by CWG	3 Jun 03
TBR/TBD7	§5.2.4, satellite transmit antenna axial ratio	Analysis/Review by CWG	3 Jun 03
TBR/TBD8	§6.1 (1), beacon EIRP	Analysis/Review by CWG	3 Jun 03
TBR/TBD9	§6.1 (2), uplink propagation impairments	Analysis/Review by CWG	3 Jun 03
TBR/TBD10	§6.1 (2), downlink propagation impairments	Analysis/Review by CWG	3 Jun 03
TBR/TBD11	§6.1 (3), minimum elevation angles at beacon and LUT	Analysis/Review by CWG and COSPAS/SARSAT	3 Jun 03
TBR/TBD12	§6.2, link availability	Analysis/Review by CWG	3 Jun 03
TBR/TBD13	§6.3, link BER	Analysis/Review by CWG	3 Jun 03
TBR/TBD14			
TBR/TBD15			
TBR/TBD16			
TBR/TBD17			
TBR/TBD18			
TBR/TBD19			
TBR/TBD20			
TBR/TBD21			
TBR/TBD22			
TBR/TBD23			
TBR/TBD24			
TBR/TBD25			
TBR/TBD26			
TBR/TBD27			
TBR/TBD28			
TBR/TBD29			
TBR/TBD30			

CWG = GOES-R Communications Working Group

8 Abbreviations and Acronyms

ALC Automatic Level Control

AM	Amplitude Modulation
AS	Archive Segment
β	Modulation Index
BCH	Bose-Chaudhuri-Hocquenghem (Forward Error Correction Code)
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BW	Bandwidth or Beamwidth (context dependent)
C3S	Command, Control and Communications Segment
CDA	Command and Data Acquisition
CDAS	Command and Data Acquisition Station
CCSDS	Consultative Committee on Space Data Systems
C/N_0	Carrier to Noise Density Ratio (dB-Hz)
COSPAS	(Russian: Cosmicheskaya Sistyema Poiska Avariynich Sudov) Space System for the Search of Vessels in Distress
CP	Circularly Polarized or Circular Polarization
DCS	Data Collection System
EIRP	Equivalent Isotropically Radiated Power
ELT	Emergency Locator Transmitter
EMWIN	Emergency Managers Weather Information Network
EPIRB	Emergency Position Indicating Radio Beacons
GEOLUT	Geostationary Local User Terminal
GOES	Geostationary Operational Environmental Satellite
GRB-F	GOES Rebroadcast - Full
GRB-L	GOES Rebroadcast - Lite
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
G/T	Gain-to-Noise Temperature Ratio (dB/K)
ICD	Interface Control Document
IRD	Interface Requirements Document
ITU	International Telecommunications Union
L-Band	1.5 - 1.6 GHz Frequency Band
LEO	Low Earth Orbit
LHCP	Left Hand Circularly Polarized
LP	Linearly Polarized or Linear Polarization
LRIT	Low Rate Information Transmission
LSS	Launch Support Segment
LUT	Local User Terminal
MCC	Cospas-Sarsat Mission Control Center

NASA	National Aeronautics and Space Administration
NOAA	National Oceanographic and Atmospheric Administration
PGDS	Product Generation and Distribution Segment
PLB	Personal Locator Beacon
PM	Phase Modulation
PSK	Phase Shift Keying
RF	Radio Frequency
RHCP	Right Hand Circularly Polarized
RVTM	Requirements Verification Traceability Matrix
SAR	Search and Rescue
SARSAT	Search and Rescue Satellite-Aided Tracking
S-Band	2.5 - 2.7 GHz Frequency Band
SS	Space Segment
TBD	To Be Determined
TBR	To Be Reviewed
TBS	To Be Supplied
TRD	Technical Requirements Document
UHF	300 - 3000 MHz Frequency Band (Generally taken to be below 1000 MHz)
UIS	User Interface Segment
USG	United States Government
X-Band	7.25 - 8.4 GHZ Frequency Band