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# **COSPAS-SARSAT GEOSAR SPACE SEGMENT COMMISSIONING STANDARD**

C/S T.013  
Issue 1 - Revision 3  
March 2021

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This document is provided as a complement to the final clean version of the document. In case of discrepancy between this marked-up version and the clean final version, the information in the clean final version shall prevail.



**COSPAS-SARSAT GEOSAR SPACE SEGMENT**  
**COMMISSIONING STANDARD**

### **History**

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## **1. INTRODUCTION**

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### **1.1 Purpose**

This document defines the recommended tests, technical measurement standards and procedures required for implementing on-orbit testing and commissioning of GEOSAR space segment payloads. Use of these measurement standards for on-orbit testing of a GEOSAR space segment will provide a standardised approach for determining the quality of the SAR instrument performance. Commissioning is a formal declaration by the specific GEOSAR commissioning authority (CA) that a SAR payload is operational with or without limitations. De-commissioning is a formal declaration by the commissioning authority that a GEOSAR SAR payload is no longer operational. The GEOSAR commissioning authority is normally the country responsible for the launch, on orbit testing and operations of the GEOSAR satellite as listed in document C/S T.011. However, a Cospas-Sarsat Participant may be the commissioning authority for GEOSAR satellites provided by international organisations.

An additional objective of this document is to ensure that measurements of GEOSAR space segment payload parameters are in accordance with a common set of test methods and definitions, so that the results may be easily evaluated.

### **1.2 Scope**

The following three phases of GEOSAR space segment on-orbit testing are addressed: initial on-orbit testing, periodic testing, and routine monitoring. The basic responsibilities, specific tests to be performed, and test methodologies are defined by this document.

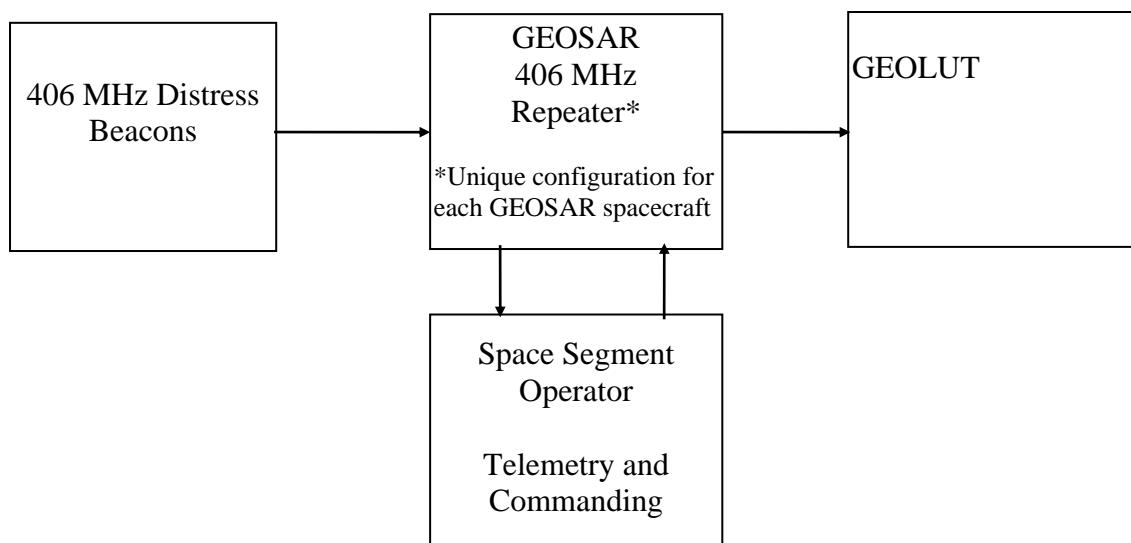
Initial on-orbit tests are performed in order to establish that a GEOSAR payload can be placed in service to support SAR operations. The initial tests focus on establishing that the GEOSAR payload will properly interface and be interoperable with the ground segment as shown in Figure 1.1. It should be noted, however, that GEOSAR space segment providers have developed unique implementations of the GEOSAR payload. These implementations include two fundamentally different designs. The GEOSAR payloads on the GOES, INSAT and Electro-L spacecraft are demodulation/remodulation type repeaters using phase modulation. The GEOSAR payloads on the MSG *and* MTG spacecraft are frequency translation type repeaters.

If results of the initial on-orbit tests confirm that values for assessment indicators are within accepted thresholds, the payload can be formally commissioned. The payload can then be used operationally and data exchanged as described in document C/S A.001, Cospas-Sarsat Data Distribution Plan.

Periodic tests to be performed year are also specified. These tests provide measurements used to confirm continued on-orbit performance of the SAR payload.

A list of recommended tests and a description of each test is provided in Annex B. The test descriptions provide sufficient detail to define the measurement method, but are not intended to be specific test procedures. It is the responsibility of the commissioning authority to develop test procedures that are traceable to the methods described in this document.

After initiation of GEOSAR operations, the space segment operator, GEOLUT operators and MCC operators routinely monitor system performance as part of normal operations. The space segment operator conducts routine monitoring of the on-orbit payload performance using telemetry and other means as deemed necessary. GEOLUT and MCC operators can also detect significant changes (e.g. loss of channel, etc.). Abnormal conditions detected by GEOLUT and MCC operators are reported to the commissioning authority for further tests and corrective action as required. If deemed necessary, operational limitations may be placed on the use of the payload or it may be de-commissioned. With respect to the MSG *and MTG* SAR payloads, the commissioning authority will advise EUMETSAT of any detected abnormal conditions, and any required tests will be developed jointly by the commissioning authority and EUMETSAT.



**Figure 1.1: GEOSAR Space Segment Interfaces**

### 1.3 Reference Documents

- a. C/S A.001: Cospas-Sarsat Data Distribution Plan.
- b. C/S A.003: Cospas-Sarsat System Monitoring and Reporting.
- c. C/S G.003: Introduction to the Cospas-Sarsat System.

- d. C/S R.006: Demonstration and Evaluation Plan for 406 MHz GEOSAR Systems.
- e. C/S T.001: Specification for Cospas-Sarsat 406 MHz Distress Beacons.
- f. C/S T.009: Cospas-Sarsat GEOLUT Performance Specification and Design Guidelines.
- g. C/S T.011: Description of the 406 MHz Payloads Used in the Cospas-Sarsat GEOSAR System.

#### **1.4 Common System Units**

The System International (SI) units of measurement will be used for exchange of interoperability parameters and test results.

Interpretation of technical terms in exchanged documentation will be in accordance with the latest edition of the "IEEE Standard Dictionary of Electrical and Electronic Terms".

- END OF SECTION 1 -

## **2. ON-ORBIT SPACE SEGMENT TESTING AND COMMISSIONING**

### **2.1 Initial On-orbit Tests**

Following the launch of each new satellite, the responsible commissioning authority conducts initial on-orbit tests to confirm that the GEOSAR payload is functioning within the performance range as specified in C/S T.011. The initial on-orbit tests to be conducted and the associated test methods are listed in Annex B. The GEOSAR space segment commissioning authorities are identified below.

<b><u>Spacecraft</u></b>	<b><u>Space Segment Operator</u></b>	<b><u>Commissioning Authority</u></b>
GOES	USA	USA
Electro-L	Russia	Russia
Insat	India	India
MSG	EUMETSAT	France <sup>+</sup>
<i>MTG</i>	<i>EUMETSAT</i>	<i>France</i>

~~Note 1: EUMETSAT will provide spacecraft command and telemetry data necessary to support testing and commissioning by France. Norway, Spain and UK GEOLUTs tracking the MSG satellite will provide processed data to support test B-11.~~

The data from the initial on-orbit tests will be used to establish baseline values of system parameters and to ensure assessment indicators are within previously established limits or to establish new limit values. The assessment indicators are identified in Annex C.

Some of the tests require beacon signal processing similar to that done by GEOLUTs in order to establish end-to-end performance. GEOSAR commissioning authorities that do not have this capability can request assistance in conducting these tests from a GEOLUT operator located in the repeater coverage area.

It is the responsibility of each commissioning authority to develop the procedures unique to the satellite and test facility for conducting tests on the GEOSAR instrument. Such procedures shall be traceable to the methods described in this document. Alternate methods can be considered but must be described in detail with the test result documentation provided with the commissioning report. In addition, other Participants may perform tests on the GEOSAR instrument. However, these tests shall conform to the methods described herein and the test procedures shall be provided to the responsible space segment operator beforehand to ensure the safety of the GEOSAR spacecraft. Furthermore, all Participants conducting tests shall conduct appropriate co-ordination within Cospas-Sarsat to ensure that there is no negative impact on Cospas-Sarsat operations.

The initial on-orbit tests provide a set of baseline values for the assessment indicators at the time the satellite begins operations. The baseline values can be compared with pre-launch

data to determine if on-orbit operation is nominal at launch, and with results from subsequent on-orbit tests to monitor on-going performance trends.

The commissioning authority will analyse the initial on-orbit test data and prepare a post launch test report. The report will include the results of the tests along with a description of the test methods sufficient to allow interpretation of the data. The test report shall be provided to the Cospas-Sarsat Secretariat as an attachment to the commissioning report.

## 2.2 Commissioning Procedure

Commissioning is a formal declaration by the commissioning authority that the on-orbit GEOSAR instrument assessment indicators meet the required compliance levels and that the equipment is operational as part of the GEOSAR system. Commissioning may be declared with operational limitations if some compliance levels are not met and limited operation is deemed feasible. In such a case the status of the GEOSAR instrument is designated as being at “limited operational capability” (LOC).

Performing the initial on-orbit tests and preparing a report may be time consuming. During this time valid operational data will normally be available from the satellite payload that is under test. In view of this, an initial operational capability (IOC) status may be declared for the payload before the commissioning report is completed. This may be done at the option of the commissioning authority after sufficient tests have been conducted to establish confidence that use of the GEOSAR data will not cause unnecessary expenditure of SAR resources.

Satellite payload IOC is declared with a SIT 605 message issued on behalf of the commissioning authority by the MCC associated with the commissioning authority. The information to be included in the SIT 605 IOC message is detailed at Annex D. Once declared, IOC status shall remain in effect until commissioning is completed which shall normally be no more than 90 days after IOC status was declared. For the first MSG SAR payload (MSG-1), IOC will last approximately 6 months, and will not be completed until all the other satellite instruments (e.g. SAR and non-SAR instruments) have been fully commissioned.

Commissioning an on-orbit GEOSAR instrument consists of confirming the basic health and safety of the payload and the measurement and analysis of post launch test data to verify compliance or non-compliance with the expected values of the assessment indicators. Figure 2.1 shows the general commissioning procedure. Upon completion of all tests, the commissioning authority will evaluate the assessment indicators and prepare a commissioning report as shown in Annex E. The commissioning report will designate the status of the GEOSAR instrument as either being either at full operational capability (FOC) or limited operational capability (LOC). The commissioning report shall be distributed by the MCC associated with the commissioning authority to all MCCs in the Cospas-Sarsat system using a SIT 605 message issued on behalf of the commissioning authority.

The commissioning authority shall provide a copy of the commissioning report to the Cospas-Sarsat Secretariat for permanent retention. In the case of the MSG *and MTG* SAR payloads, the commissioning authority will provide copies of all test results and commissioning reports to EUMETSAT. The Secretariat will provide copies of the report to Cospas-Sarsat Participants upon request.

### **2.3 Satellite System Data**

In order for Cospas-Sarsat to operate the GEOSAR system at either an IOC, LOC or FOC status, the GEOSAR space segment operator shall provide the MCC associated with the commissioning authority with the satellite/payload information necessary for conducting daily operations. This MCC shall distribute the information to GEOLUT operators in accordance with Cospas-Sarsat data distribution procedures as specified in document C/S A.001. Examples of such data are satellite ephemeris and status messages as needed to inform Cospas-Sarsat about the state of the GEOSAR instrument. The distribution of satellite ephemeris, which may precede declaration of IOC status, shall not in itself be taken as a declaration of IOC status.

### **2.4 Periodic Tests**

Periodic technical tests shall be performed yearly on each on-orbit GEOSAR instrument by the commissioning authority to confirm that the assessment indicators remain within the accepted limits and that the GEOSAR system under evaluation does not adversely affect SAR services. The data obtained from periodic testing can also be used to provide trend data for forecasting satellite operations and projecting the remaining life of the GEOSAR payload. The specific periodic tests to be conducted for each payload are listed at Annex B.

A copy of all test results shall be provided to the Secretariat for permanent retention. In the case of the MSG *and MTG* payloads, the commissioning authority will provide copies of the test results to EUMETSAT. Should the results of the periodic tests indicate a problem with the SAR payload then the appropriate course of action described in section 2.7 should be followed.

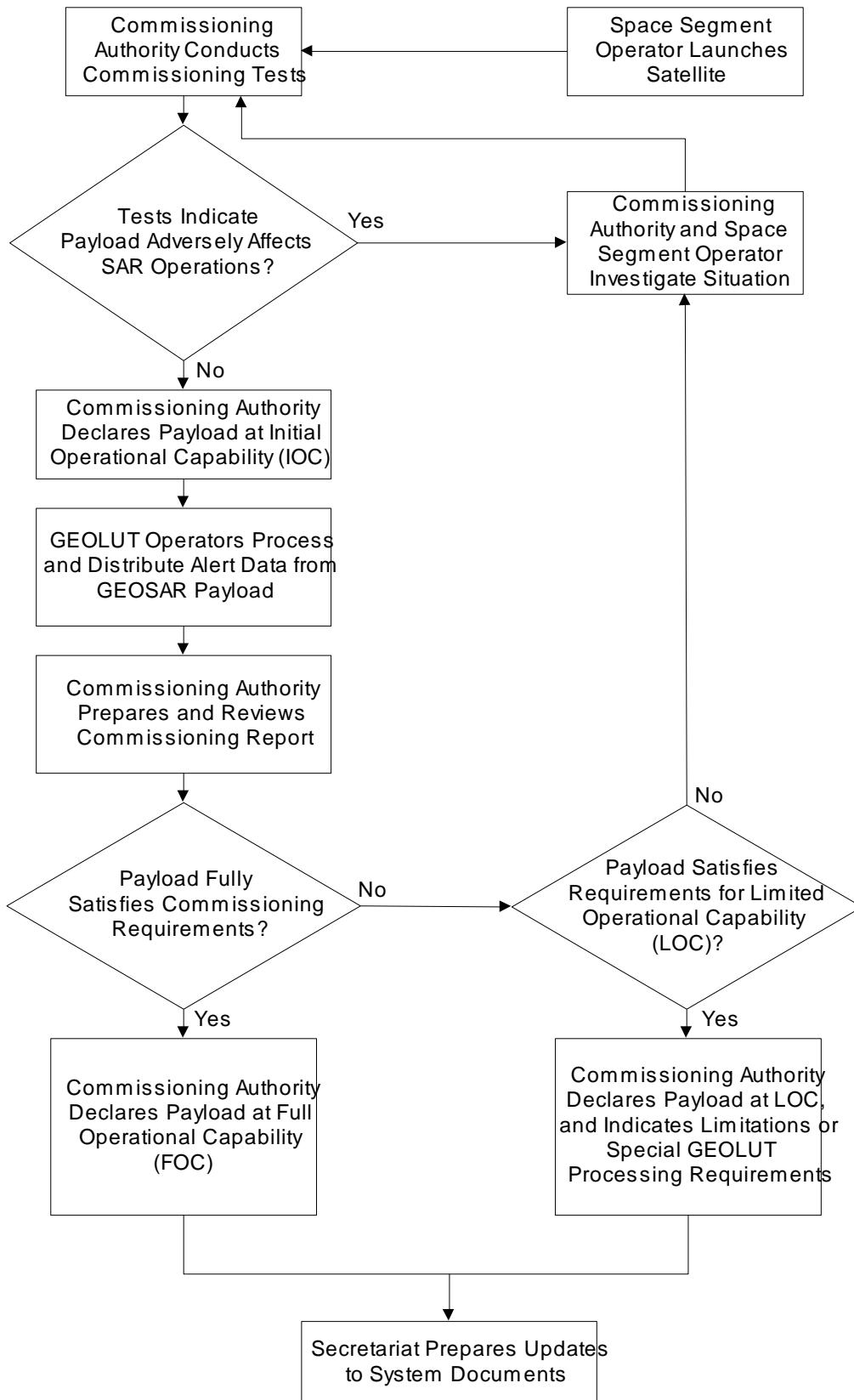
### **2.5 Routine Monitoring of the Space Segment**

Routine monitoring of the space segment shall be performed by the space segment operator, as well as GEOLUT and MCC operators. By monitoring the satellite telemetry information the space segment operator might be able to identify potential problems before they impact on SAR services. GEOLUT operators are able to identify problems by noting changes in GEOLUT performance (e.g. satellite tracking performance or number of processing anomalies generated), whereas MCC operators might be able to identify problems by comparing the alerts produced by the GEOSAR system with information concerning distress events obtained from other sources.

All problems or potential problems with the payload detected by either a space segment, GEOLUT, or an MCC operator shall be reported to the applicable commissioning authority. In the case of the MSG *and* MTG SAR payloads, the commissioning authority will advise EUMETSAT of all / any problems, and actions proposed to investigate the matter. The commissioning authority shall then conduct tests to confirm the health of the payload. Should these tests indicate a problem with the SAR payload then the appropriate course of action described in section 2.7 shall be followed.

## 2.6 De-commissioning Procedure

De-commissioning is a formal declaration by the GEOSAR commissioning authority that a GEOSAR payload is no longer a part of the GEOSAR system. A GEOSAR instrument that cannot meet the performance requirements for reliable Cospas-Sarsat service will be de-commissioned. An operational GEOSAR instrument may also be de-commissioned by the space segment operator due to general spacecraft health and safety issues. In this case, the spacecraft operator shall notify the commissioning authority that the SAR instrument should be de-commissioned. The commissioning authority would be responsible for distributing this information via the MCC network, and providing a copy to the Secretariat for permanent retention. A de-commissioned payload can later be re-commissioned, with or without limitations, based on an evaluation of current values of the assessment indicators and the need within Cospas-Sarsat.



Note: The MSG *and* MTG Payload Commissioning Authority will provide EUMETSAT copies of all MSG-Payload test results and reports.

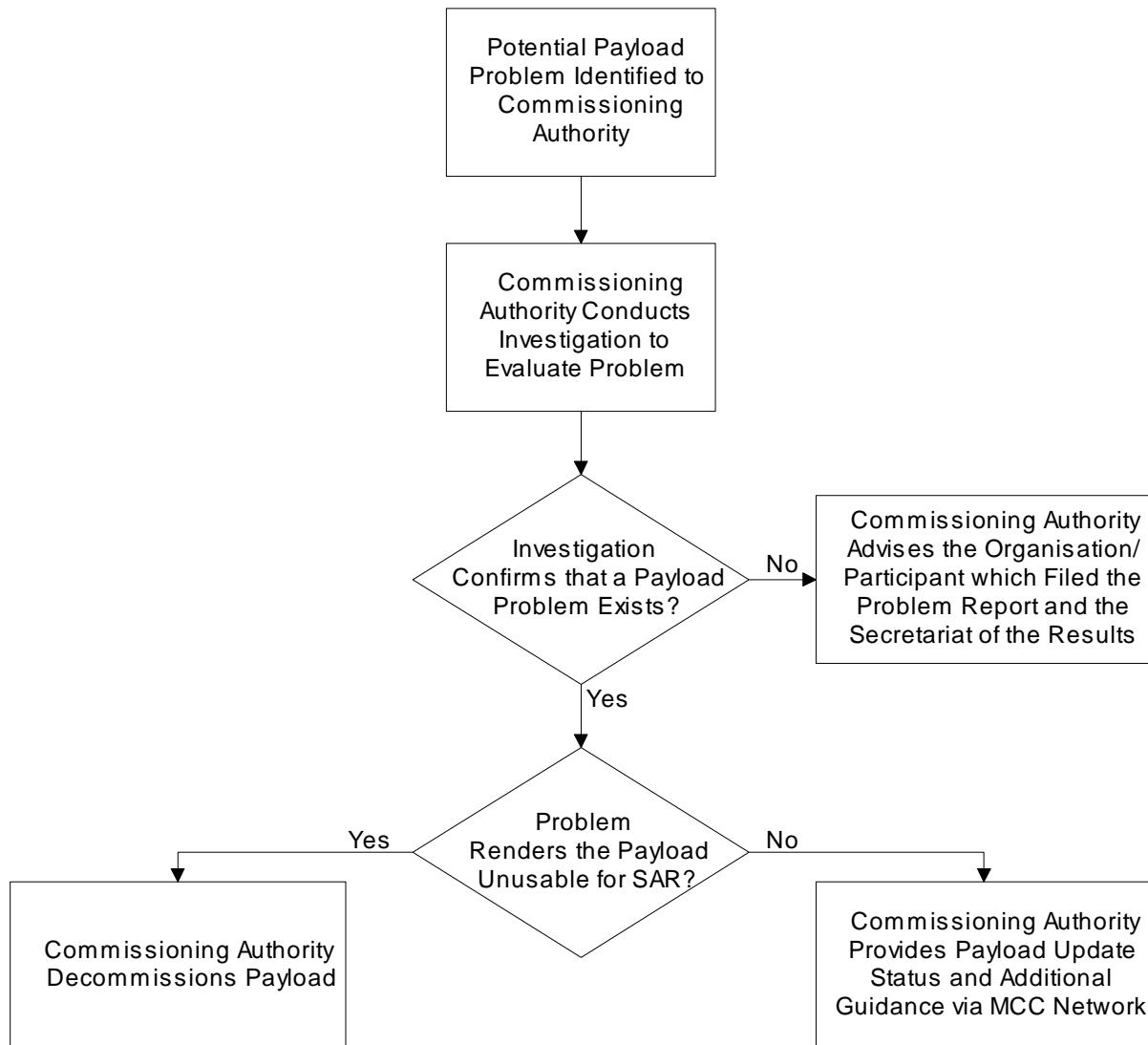
**Figure 2.1: GEOSAR Payload Commissioning Procedure**

## 2.7 Space Segment Problem Reporting and Investigation Procedures

Any space segment, GEOLUT or MCC operator that detects anomalies of a GEOSAR instrument during routine monitoring or system operation shall inform the relevant commissioning authority so that special tests can be conducted and possible corrective action (e.g., switch to backup payload, etc.) taken. GEOLUT and MCC operators will report problems to the responsible commissioning authority through the associated MCC in accordance with procedures given in C/S A.001, and space segment operators shall report anomalies to the commissioning authority via the most effective means available.

Upon being made aware of a possible problem with the GEOSAR payload, the commissioning authority shall advise the space segment operator, and conduct an investigation to evaluate the status and performance of the instrument. Based on the results of the investigation, the commissioning authority shall take one of the courses of action described below.

- a. Should the investigation identify a serious problem with the payload which renders it unusable for SAR purposes, the commissioning authority shall decommission the payload in accordance with section 2.6.
- b. Should the investigation identify a problem which confirms degraded payload performance, but indicates that the instrument is still useful for SAR purposes, the commissioning authority shall distribute an update of the payload status via the MCC network, with a copy also provided to the Secretariat and to the space segment operator. The update shall specifically identify:
  - the problem with the payload;
  - the impact on GEOLUT processing;
  - the impact on the quality of distress alerts produced; and
  - any special GEOLUT processing required.
- c. Should the investigation not confirm the problem or conclude that there is a problem which does not impact on GEOSAR performance, the commissioning authority shall liaise with the organisation which identified the problem to confirm that GEOSAR performance is not affected. A copy of the conclusions shall also be provided to the Secretariat for retention. There would be no requirement to advise other Cospas-Sarsat Participants of the results of the investigation in such a circumstance.



Note: The MSG *and* MTG Payload Commissioning Authority will provide EUMETSAT copies of all MSG-Payload test results and reports.

**Figure 2.2: GEOSAR Problem Reporting and Investigation Procedures**

- END OF SECTION 2 -

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**ANNEXES TO THE DOCUMENT  
GEOSAR  
SPACE SEGMENT  
COMMISSIONING STANDARD**

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**ANNEX A****LIST OF ACRONYMS USED IN C/S T.013**

AGC ..... automatic gain control  
ALC ..... automatic level control

BW ..... bandwidth

C/N ..... carrier-to-noise power ratio  
C/N<sub>o</sub> ..... carrier-to-noise density ratio  
cw ..... continuous wave

dB ..... decibel  
dB<sub>Hz</sub> ..... decibel relative to one Hertz  
dB<sub>m</sub> ..... decibel above one milliwatt  
dB<sub>W</sub> ..... decibel above one Watt

EIRP ..... equivalent isotropically radiated power  
EOC ..... edge of coverage

f<sub>c</sub> ..... carrier frequency  
FOC ..... full operational capability  
FOV ..... field of view

GEOLUT ..... LUT in a GEOSAR system  
GEOSAR ..... geostationary satellite system for search and rescue  
GOES ..... Geostationary Operational Environmental Satellite  
G/T ..... gain-to-noise temperature ratio

IF ..... intermediate frequency  
INSAT ..... Indian National Satellite  
IOC ..... interim operational capability

K ..... Kelvin  
k ..... Boltzmann's constant  
kHz ..... kilohertz

LOC ..... limited operational capability  
LNA ..... low noise amplifier

MHz ..... megahertz  
ms ..... milliseconds  
MSG ..... Meteosat Second Generation  
*MTG* ..... *Meteosat Third Generation*  
mW ..... milliwatt

$N_o$  .....noise power spectral density

PDVM .....probability of detecting a valid message.

RBW .....resolution bandwidth

RHCP .....right hand circular polarisation

SAR .....search and rescue

S/N<sub>o</sub> .....signal-to-noise density ratio

-END OF ANNEX A-

**ANNEX B****GEOSAR SPACE SEGMENT TESTING**

The table below identifies the minimum set of post launch tests to be completed by the space segment operator in order to establish initial commissioning of a GEOSAR payload. Each space segment operator is also encouraged to conduct other tests that may more fully characterise payload performance. Selected tests are repeated yearly.

**Table B.1: List of Post Launch Tests**

Parameter Tested	GOES	INSAT	MSG	Electro-L	MTG
B.1 Equivalent Isotropically Radiated Power (EIRP) in SAR Channel	1,2	1,2	1,2	1,2	1,2
B.2 Spectral Occupancy of the Downlink	1	1	1	1	1
B.3 Spurious Output Levels	1	1	1	1	1
B.4 G/T of the 406 MHz Repeater	1,2	1,2	1,2	1,2	1,2
B.5 Channel Bandwidth and Amplitude Ripple	1,2	1,2	1,2	1,2	1,2
B.6 Downlink Carrier Frequency	1,2	1,2	1,2	1,2	1,2
B.7 ALC Dynamic Range	1	1	N/A	N/A	N/A
B.8 Modulation Index	1	1	N/A	1	N/A
B.9 Translation Frequencies	1,2	1,2	1,2	1,2	1,2
B.10 Intermodulation and Harmonic Levels	1	1	1	1	1
B.11 Beacon signal processing	1	1	1	1	1

Notes: 1. Commissioning test.  
2. This test is also performed periodically at yearly intervals.

The following pages of this annex provide a general description of each test. It should be noted, however, that each space segment operator has developed a unique implementation of the GEOSAR payload. These implementations include two fundamentally different designs. The GEOSAR payloads on the GOES Electro-L and INSAT spacecraft are remodulation type repeaters using phase modulation. The GEOSAR payload on the MSG *and* MTG spacecraft *are* frequency translation type repeaters. It is the responsibility of each commissioning authority, in co-operation with the space segment operator, to develop detailed procedures unique to his ground test facility for conducting these tests. Such procedures where possible shall be traceable to the methods described in this document. Alternate methods can be

considered but must be agreed to in advance by the space segment operator and described in detail by the commissioning authority as part of the post launch test report.

The performance parameters to be measured by these tests and their values are listed in Annex C as assessment indicators.

## **B.1 EIRP IN SAR CHANNEL**

### **B.1.1 OBJECTIVE**

The objective of this test is to measure the SAR instrument downlink equivalent isotropically radiated power (EIRP). The measured value will be compared with the level specified in the Description of the 406 MHz Payloads Used in the Cospas-Sarsat System, C/S T.011. The test should be conducted for each operational mode and redundancy configuration.

### **B.1.2 PROCEDURE**

The general procedure to be adopted for remodulation repeaters (e.g. GOES and INSAT payloads) for determining the EIRP is to command the phase modulation off and measure the downlink carrier level at the ground receiving station. With the phase modulation off the total power is in the carrier. A common technique is to measure the  $C/N_0(dn)$  at an IF point in the receiving ground station. A spectrum analyser is the preferred instrument for use in making the measurement. The EIRP is then derived using the following link equation.

$$EIRP = C/N_0(dn) - G/T(gs) + L_{path} + L_{pol} + k \text{ (dBm)}$$

Where:

$C$  = SAR instrument downlink carrier at the receiving station (dBm)

$N_0(dn)$  = noise power spectral density at the ground receiving system. The SAR transponder up-link noise is not included in  $N_0(dn)$  since the phase modulation is turned off. (dBm/Hz)

$G/T(gs)$  = receiving station antenna gain to system noise temperature ratio. (dB/K)

$L_{path}$  = free space path loss from the satellite to the ground station. (dB)

$L_{pol}$  = loss due to polarisation mismatch between the ground receive antenna and the satellite antenna. (dB)

$k$  = Boltzmann's constant = -198.6 (dBm/Hz-K)

Measure the downlink received  $C/N$  in the ground receiver IF using a spectrum analyser resolution bandwidth setting such that  $C/N \geq 20$  dB. The value read for  $C$  can then be taken to be entirely due to the carrier since the carrier power is 100 times the noise power. Position the analyser marker away from the carrier for making the  $N_0(dn)$  measurement.  $N_0(dn)$ , and possibly  $C/N_0(dn)$ , can be measured directly using the spectrum analyser if it has an automatic noise density-measuring feature. If not, the noise power,  $N$ , in the resolution

bandwidth can be converted to  $N_o(dn)$  by applying the bandwidth correction plus any other correction factors specified for the analyser.

## **B.2 SPECTRAL OCCUPANCY OF THE DOWNLINK**

### **B.2.1 OBJECTIVE**

The objective of this test is to measure the spectral occupancy of the downlink spectrum in order to identify normal in-band operation and the presence of any out-of-band emissions. The test must be performed separately in each operating mode of the SAR instrument.

### **B.2.2 PROCEDURE**

The downlink spectrum in a 1 MHz band centred on the downlink carrier is measured using a spectrum analyser connected in the ground receiver 1<sup>st</sup> IF ahead of any narrow band filtering and the phase demodulator. A spectrum analyser resolution bandwidth of 1 kHz or lower is recommended. The measurement should be made if possible during a period when no 406 MHz band interfering signals are being received and retransmitted by the spacecraft. Several plots of the measured spectrum should be taken, particularly if abnormal performance is suspected. Sufficient calibration data must be provided in order to relate the measured carrier component to the spacecraft output (using link budget). The test should be repeated in a 2 MHz band centred on the downlink carrier.

The spectrum is analysed for the presence of any anomalous spectral emissions. Since there is very little Doppler frequency variation associated with geostationary satellites, signals that constantly appear in the spectrum at fixed frequencies are due to either on board electromagnetic interference (EMI) or external interference. The source of any observed signals may possibly be determined by comparing spectral plots taken at various times throughout the day or over a number of days. Data from the LEOSAR system may also be used to assist in identifying signals that originate from external sources.

## **B.3 SPURIOUS OUTPUT LEVELS**

### **B.3.1 OBJECTIVE**

The objective of this test is to determine the frequency and level referred to the receiver input of any spurious signals within the GEOSAR repeater bandwidth.

### **B.3.2 PROCEDURE**

Spurious signals within the repeater bandwidth can be monitored in the demodulated baseband spectrum using a spectrum analyser. These measurements should be made as accurately as possible; therefore, they should be made with as small a resolution bandwidth as practical ( $\leq 100\text{Hz}$ ). The baseband is approximately 100 kHz and a FFT type spectrum analyser, if available, is a good choice for the measurement instrument. Care must be exercised in identifying spurious signals generated by on-board equipment. The signals are in general at a constant frequency; however, since there is very little GEOSAR Doppler shift associated with terrestrially emitted signals in the 406 MHz band these signals also will

appear at a constant frequency. It may be necessary to take several spectrum plots over a number of days to assist in identifying on-board signals from terrestrial emitters. The test personnel can also ask for assistance from LEOLUT operators in identifying terrestrial emitters. The LEOSAR spacecraft can identify these signals due to the Doppler at the LEOSAR spacecraft.

The frequency of any in-band spurious signals can be read using the spectrum analyser marker controls. The level of spurious signals at the receiver input can be estimated by transmitting a known reference signal to the satellite to compare against the spurious signal. The reference signal should be within a few kilohertz of the signal and can be adjusted to match the spurious signal level. However, care must be taken to not overload the repeater. The level of the reference signal at the receiver input can be estimated by performing a link calculation.

## B.4 G/T OF THE 406 MHz REPEATER

### B.4.1 OBJECTIVE

The objective of this test is to measure the 406 MHz SAR receiver antenna gain-to-noise temperature ratio,  $G/T_{(406)}$ . The measured value will be compared with the level specified in C/S T.011, “Description of the 406 MHz Payloads Used in the Cospas-Sarsat GEOSAR System”. The test should be conducted for each available GEOSAR receive antenna and LNA configuration (redundant channels, etc.).

### B.4.2 PROCEDURE

The LNA gain on GEOSAR instruments is large enough so that the G/T is established by the antenna and LNA combination. Therefore, the measurement can be made in either the wideband or narrow band mode.

The on orbit  $G/T_{(406)}$  can be derived by using the following link equation.

$$\frac{G}{T}(406) = \frac{C}{N_o}(up) - EIRP(up) + L_{path} + L_{pol} + k$$

Where

$$\frac{C}{N_o}(up) = \text{carrier to noise density ratio in the SAR repeater. (dBHz}^{-1}\text{)}$$

$EIRP(up)$  = known up-link EIRP. (dBm)

$L_{path}$  = up-link free space path loss. (dB)

$L_{pol}$  = polarisation mismatch loss between the up-link antenna and the satellite receive antenna. (dB)

$K$  = Boltzmann's constant = -198.6 (dBm/Hz-K)

$C/N_o(up)$  is calculated from the overall  $C/N_o(\text{total})$  measured at the ground test facility by subtracting out the ground station receiver noise. The  $N_o$  (total) observed at the ground

station consists of two parts;  $N_o(\text{total}) = N_o(\text{up}) + N_o(\text{gs})$  where  $N_o(\text{gs})$  is the ground station receiver noise.  $N_o(\text{gs})$  can be measured by pointing the ground station antenna away from the GEOSAR spacecraft but not in the beam width of stellar sources emitting high radio frequency energy levels.

The general procedure is as follows.

- a. Up-link a known EIRP ( $\geq 40$  dBm) at 406.025 MHz.
- b. Monitor the received signal using a spectrum analyser. This can be done after demodulation and/or filtering to baseband. Adjust ground station antenna azimuth and elevation to maximise the received level. Set analyser resolution bandwidth such that  $C/N(\text{total}) \geq 20$  dB. Measure values of  $C/N_o(\text{total})$ ,  $C$ , and  $N_o(\text{total})$ . The noise spectral density values can be measured directly using the spectrum analyser if it has an automatic noise density measuring feature. If not, the noise power,  $N(\text{total})$  measured in the analyser resolution bandwidth can be converted to  $N_o(\text{total})$  by applying the bandwidth correction plus any other correction factors specified for the analyser.
- c. Adjust the ground station antenna pointing such that it points away from GEOSAR by at least  $15^\circ$  but not in the field of view (FOV) of stellar sources emitting high radio frequency energy levels. Measure the clear sky ground station receiver noise,  $N_o(\text{gs})$ .
- d. Compute  $N_o(\text{up}) = N_o(\text{total}) - N_o(\text{gs})$  and use the value to determine  $C/N_o(\text{up})$  (convert as needed between numerics and dB).
- e. Derive  $\frac{G}{T}(406) = \frac{C}{N_o}(\text{up}) - \text{EIRP}(\text{up}) + L_{\text{path}} + L_{\text{pol}} + k$

## B.5 CHANNEL BANDWIDTH AND AMPLITUDE RIPPLE

### B.5.1 OBJECTIVE

The objective of this test is to measure the bandwidth and amplitude ripple in the GEOSAR repeater channel. The test must be performed for each channel bandwidth mode of operation. The test can be performed in the fixed gain mode on transponders that have selectable ALC ON/OFF, however, it is desirable to perform the test for both the fixed gain and ALC mode configurations.

### B.5.2 PROCEDURE

The level of 406 MHz beacon signals received at the spacecraft is sufficiently small such that under normal situations a band of white noise generated by the LNA is transmitted on the channel. The amplitude ripple of the channel can be estimated by observing this band of noise power at the ground test facility. The observation should be done during a "quiet" period, i.e. no interference or large test inputs. Swept frequency techniques may be used as an alternate procedure.

#### B.5.2.1 Channel frequency response (phase modulation repeater)

- a. Monitor the downlink baseband signal after the ground station phase demodulator with the spacecraft in the narrowband mode and ALC disabled (fixed gain mode). The analyser centre frequency, resolution bandwidth and span should be adjusted to appropriately display the channel data.
- b. Take a spectrum plot during a quiet period.
- c. Use the spectrum analyser offset markers to identify the 3-dB bandwidth. Print a record for the test report.
- d. Repeat steps a through c for the following modes as applicable: narrowband/ALC ON, wideband/ALC OFF and wideband/ALC ON.

#### B.5.2.2 Channel frequency response (frequency translator repeater)

- a. With the spacecraft in the narrowband mode and ALC disabled, monitor the downlink signal in the ground station receiver IF ahead of any filtering that would corrupt the channel measurement. The analyser centre frequency, resolution bandwidth and span should be adjusted to appropriately display the channel data.
- b. Take a spectrum plot during a quiet period.
- c. Use the spectrum analyser offset markers to identify the 3-dB bandwidth. Print a record for the test report.
- d. Repeat steps a through c for the modes as applicable: narrowband/ALC ON, wideband/ALC OFF and wideband/ALC ON.

## B.6 DOWNLINK CARRIER FREQUENCY

### B.6.1 OBJECTIVE

The objective of this test is to measure the GEOSAR phase modulation type repeater downlink carrier frequency.

### B.6.2 PROCEDURE

The frequency of the downlink signals received at the ground test facility can be measured with a spectrum analyser that has a counter mode with a 1 Hz resolution. The downlink signal for the phase modulation type transponder contains sufficient carrier level for isolating and measuring the carrier frequency. Alternately the receiver can be turned OFF so that no modulation is present on the carrier when making the measurement.

The general procedure is as follows.

- a. Monitor the downlink frequency in the 1<sup>st</sup> IF with the spectrum analyser. Select a resolution bandwidth such that the carrier can be isolated from the modulation sidebands and the C/N ratio is  $\geq 20$  dB.
- b. Measure the carrier frequency using the analyser frequency counter mode. Alternate techniques may be used if the analyser does not have the counter mode.
- c. A minimum of 20 measurements at 1-minute intervals should be taken and averaged to determine the carrier frequency. This data should also be examined to determine if carrier frequency drift is occurring.

## B.7 ALC DYNAMIC RANGE

### B.7.1 OBJECTIVE

The objective of this test is to measure the gain transfer function with the GEOSAR transponder in the ALC mode.

### B.7.2 PROCEDURE

The gain transfer function is a measure of the transponder output power versus transponder input power. This procedure uses unmodulated carrier signals only. The uplink signal EIRP is varied in level over the dynamic range of the SAR receiver, from input noise to the maximum allowable signal into the transponder. The resulting downlink carrier level,  $C_d$ , is measured in the pre-detection IF bandwidth using a spectrum analyzer. This measurement can also be made after phase demodulation for phase modulation type SAR repeaters such as those on the GOES spacecraft. Plot the transfer curve using the measured data.

The general procedure is as follows:

- a. Begin with no uplink. Monitor the downlink to ensure that no active beacons or interference signals are present. Record the downlink carrier signal strength. Note that the level of the 1544.5 MHz carrier for the phase modulation repeaters will remain essentially constant throughout the test.
- b. Establish a CW uplink signal at a frequency near mid-band and an EIRP of 5 Watts. Observe this signal on the downlink using the spectrum analyzer. Increase the uplink signal level to the point where the observed downlink signal,  $C_d$ , does not continue to increase, i.e. the AGC is operating at the upper limit of the dynamic range. Record the uplink EIRP and the value of the measured downlink signal and the SAR receiver  $N_o$  (measured a few kHz away from  $C_d$  using the spectrum analyzer). The downlink should be free of interference when making these measurements.
- c. Decrement the CW uplink signal in 1 dB steps; monitor the downlink to ensure there is no interference present and record the measured values of  $C_d$ ,  $N_o$  and the uplink EIRP. Continue to reduce the uplink signal by 1 dB and make the measurements until  $C_d$  approaches the receiver noise level.
- d. Repeat steps a through c for the spacecraft modes as applicable: narrowband/ALC ON, wideband/ALC ON.

The following equation and data from this test may also be used to derive an estimate of SAR repeater gain to noise temperature ratio, G/T(406).

$$\frac{G}{T}(406) = \frac{C}{N_o}(\text{up}) - \text{EIRP}(\text{up}) + L_{\text{path}} + L_{\text{pol}} + k$$

Where

$$\frac{G}{T}(406) = \text{SAR 406 MHz repeater gain to noise temperature ratio (dBK}^{-1}\text{).}$$

$$\frac{C}{N_o}(\text{up}) = \text{carrier to noise density ratio in the SAR repeater. (dB-Hz).}$$

$N_o$  = noise power spectral density in a 1 Hz bandwidth.

$\text{EIRP}(\text{up})$  = known up-link EIRP. (dBm).

$L_{\text{path}}$  = up-link free space path loss. (dB).

$L_{\text{pol}}$  = polarisation mismatch loss between the up-link antenna and the satellite receive antenna. (dB).

$K$  = Boltzmann's constant = -198.6 (dBm/Hz-K).

The AGC functions to maintain a constant power at the spacecraft receiver output. Note the point on the AGC curve that is 3 dB below the maximum. At this point the test uplink input referred to the SAR low noise amplifier input,  $C_u$ , and total receiver noise power,  $N$ , in the channel bandwidth are equal; therefore,  $C_u/N = 0$  dB. Knowing also that  $N = kTB = N_o B$  where  $B$  is the channel bandwidth, the value of  $C/N_o(\text{up}) = B$  for this specific uplink signal.

The G/T(406) can be derived by using the above equation with  $\frac{C}{N_o}(\text{up}) = B$  and  $\text{EIRP}(\text{up}) =$  the value of the uplink EIRP used for the point on the AGC curve that is 3 dB below the maximum value.

## B.8 MODULATION INDEX

### B.8.1 OBJECTIVE

The purpose of this test is to measure the modulation index for phase modulated type GEOSAR repeaters. The test should be conducted for each of the available bandwidth/ALC operating modes: narrow band/ALC ON, narrow band/ALC OFF, wide band/ALC ON, and wide band/ALC OFF.

### B.8.2 PROCEDURE

The difference in the received downlink carrier level when the SAR receiver is switched from OFF to ON (i.e. carrier suppression technique) is measured at the ground test facility. Distress beacon signals are very small resulting in the receiver output being mostly noise. This band of noise (wide band or narrow band) is phase modulated onto the GEOSAR spacecraft downlink carrier. The general procedure is as follows and should be repeated for each bandwidth/ALC mode of operation.

- a. Configure the space segment receiver to OFF. Monitor the downlink carrier with a spectrum analyser. Select an analyser resolution such that the received  $C/N \geq 20$  dB. Record the level of  $C_{Rx\_off}$ .
- b. Configure the space segment receiver to ON. Monitor the downlink carrier with a spectrum analyser. Select an analyser resolution such that the received  $C/N \geq 20$  dB. Record the level of  $C_{Rx\_on}$ . The downlink spectrum should be monitored during the measurement of  $C_{Rx\_on}$  to assure that no large interfering signal is in the band when making the measurements. This condition would result in higher values of modulation index.
- c. Compute value of carrier suppression as of  $C_{Rx\_off} - C_{Rx\_on}$ .
- d. Repeat steps a through c for each bandwidth/ALC mode.
- e. The test data should include the carrier suppression values with the associated modulation index.

## B.9 TRANSLATION FREQUENCIES

### B.9.1 OBJECTIVE

A 406 MHz signal at the repeater input is translated to a specific frequency in the downlink spectrum as a function of the spacecraft local oscillators. The objective of this is to measure the frequency in the downlink to which a 406 MHz beacon signal is translated.

### B.9.2 PROCEDURE

The frequency of the downlink signals received at the ground test facility can be measured with a spectrum analyser that has a counter mode with a 1 Hz resolution. A 406 MHz band cw test signal at a precise frequency must be transmitted from the ground test facility to the satellite for use in measuring the translation frequency. In order to obtain accurate measurements, the cw test uplink signal, the spectrum analyser, and all down conversions in the ground station receiver must be locked to a precision frequency standard.

#### B.9.2.1 Beacon to downlink translation frequency (phase modulation repeater).

This test can be performed in either the wideband or narrowband mode.

- a. With the spacecraft in the wideband mode, uplink a 406.05 MHz (406.025 MHz if in narrowband mode) cw carrier at 10 dBW EIRP.
- b. Monitor the translated downlink frequency in the baseband spectrum after phase demodulation. Select a spectrum analyser resolution bandwidth such that the received signal has a C/N ratio  $\geq 20$  dB.
- c. Measure the carrier frequency using the analyser frequency counter mode. Alternate techniques may be used if the analyser does not have the counter mode.
- d. A minimum of 20 measurements at 30-second intervals should be taken and averaged to determine the carrier frequency. This data should also be examined to determine if the translation oscillators are drifting in frequency.

#### B.9.2.2. Beacon to downlink translation frequency (frequency translation repeater).

- a. With the spacecraft in the wideband mode, uplink a 406.05 MHz (406.025 MHz if in narrowband mode) cw carrier at 10 dBW EIRP.
- b. Monitor the translated downlink frequency in the 1<sup>st</sup> IF with the spectrum analyser. Select a resolution bandwidth such that the received signal has a C/N ratio  $\geq 20$  dB.

- c. Measure the carrier frequency using the analyser frequency counter mode. Alternate techniques may be used if the analyser does not have the counter mode.
- d. A minimum of 20 measurements at 30-second intervals should be taken and averaged to determine the carrier frequency. This data should also be examined to determine if the translation oscillators are drifting in frequency.

## **B.10 INTERMODULATION LEVELS**

### **B.10.1 OBJECTIVE**

The objective of this test is to determine the levels of any intermodulation products in the SAR channel. The SAR transponder operates with inputs from multiple users at different frequencies in the band. There are also uplinks from unauthorized users which are called interferers. If the levels of intermodulation products in the transponder band are too high, they can interfere with beacon signals that are at or near the same frequencies as the intermodulation products.

The test should be conducted in all modes as applicable to the specific type of GEOSAR repeater.

### **B.10.2 PROCEDURE**

Two equal large level carriers at 1 kHz separation shall be applied at the transponder input. The downlink spectrum is examined with a spectrum analyzer in the pre-detection IF bandwidth for third order intermodulation products. This measurement can also be made after phase demodulation for phase modulation type SAR repeaters such as those on the GOES spacecraft. A record of the measured spectrum should be recorded to support analysis and for inclusion in the test report. The level of intermodulation products in dB below the test signal output shall be measured.

#### **B.10.2.1 Procedure for SAR repeaters on GOES spacecraft.**

- a. Determine the test signal input power levels for the repeater mode being tested. Each test signal,  $S_{in}$ , must be 7 dB above total receiver noise level for modes with ALC ON. When in fixed gain mode (FGM),  $S_{in}$ , is set to 2 dB above total receiver noise level.

The receiver noise is equal to  $kTB_n$  where  $B_n$  is the noise bandwidth of the receiver for the specific operating mode.  $B_n$  can be estimated by using the 3 dB filter bandwidth measured during test B.5.

The input  $S_{in}/N_0$  of the test signal can be determined as follows.

$$\text{ALC modes} \quad S_{in}/N_0 = B_n + 7 \text{ dB-Hz}$$

$$\text{FGM} \quad S_{in}/N_o = B_n + 2 \text{ dB-Hz}$$

b. Select a spacecraft configuration to be tested and monitor the received baseband using the spectrum analyzer. Uplink two test signals with the frequencies and power necessary to achieve the  $S_{in}/N_o$  values listed in the following table.

Configuration	F1 (MHz)	F2 (MHz)	B <sub>n</sub> (dB-Hz)	S <sub>in</sub> /N <sub>o</sub> (dB-Hz)	Specification Relative to S <sub>in</sub>
WB- ALC	406.0495	406.0505	B <sub>wb</sub> per test B.5	B <sub>wb</sub> + 7	-30 dB
WB-Fixed Gain	406.0495	406.0505	B <sub>wb</sub> per test B.5	B <sub>wb</sub> + 2	-20 dB
NB – ALC	406.0245	406.0255	B <sub>nb</sub> per test B.5	B <sub>nb</sub> + 7	-30 dB
NB- Fixed gain	406.0245	406.0255	B <sub>nb</sub> per test B.5	B <sub>nb</sub> + 2	-20 dB

B<sub>wb</sub> is the receiver noise bandwidth measured per test B.5 when in the wide band mode.

B<sub>nb</sub> is the receiver noise bandwidth measured per test B.5 when in the narrow band mode.

c. Record the spectrum. For wideband examine the spectrum from 48 to 53Khz for spurious signals. For narrowband, examine the spectrum from 23 kHz to 28 kHz for spurious signals. Any spurious signals observed must be below the input signal in accordance with column 6 of the above table.

d. Change modes and repeat step a and b until all modes have been tested.

## B.11 BEACON SIGNAL PROCESSING

### B.11.1 OBJECTIVE

The purpose of this test is to demonstrate that 406 MHz beacon signals relayed through the GEOSAR repeater are properly processed by a GEOLUT with sufficient reliability for distribution within the Cospas-Sarsat network.

### B.11.2 PROCEDURE

Beacon output signals at specific levels will be transmitted to the GEOSAR and relayed to a GEOLUT for reception and processing. The test, therefore, requires use of beacon signal processing as done by a GEOLUT. Any GEOSAR spacecraft operator that does not have this capability can request assistance from a GEOLUT operator located in the coverage area.

This test is based on a modification of test T-1, Processing Threshold and System Margin, as described in document C/S R.006. A controlled test beacon simulator is necessary for the test. It is required that the EIRP of this beacon simulator be adjustable, that multiple identification codes be transmitted, and that the burst transmissions are controllable in message blocks as described in C/S R.006. The general procedure is as follows.

- a. Place the beacon simulator in the satellite FOV with an elevation angle to the satellite > 5 degrees.
- b. Configure the satellite for the wideband/fixed gain mode.
- c. Configure the beacon simulator as follows:
  - (i) Set the EIRP to +37 dBm.
  - (ii) Use 3 to 4 identification codes to allow immediate restarting of the test after a GEOLUT measurement.
  - (iii) Transmit 100 message blocks.
- d. GEOLUT operator measure the number of valid messages received and the C/N<sub>0</sub> of the beacon message for the +37 dBm signal.
- e. Calculate the probability of detecting a valid message (PDVM) as the number of valid messages processed divided by total number of message blocks transmitted. The PDVM should be >0.99.
- f. Reset the beacon simulator as follows:
  - (i) Reduce the EIRP from +37 dBm by (C/N<sub>0</sub> - 26) dB where C/N<sub>0</sub> is the value measured in step d. This will provide a received beacon signal with a C/N<sub>0</sub> ≈ 26 dB-Hz.
  - (ii) Use the same 3 to 4 identification codes as in step 3 to allow immediate restarting of the test after a GEOLUT measurement.
  - (iii) Transmit 100 message blocks.
- g. Calculate the PDVM as the number of valid messages processed divided by total number of message blocks transmitted. The PDVM should be >0.95.

-END OF ANNEX B-

**ANNEX C****GEOSAR SPACE SEGMENT ASSESSMENT  
INDICATORS / COMPLIANCE LEVELS****Table C.1: GOES Space Segment Assessment Indicators / Compliance Levels**

Assessment Indicator	Compliance Level Reference
L-band EIRP	C/S T.011, Table 3.3
Spectral occupancy (of downlink)	C/S T.011, Figure 3.2
G/T of 406 MHz receiver	C/S T.011, Table 3.2
Modulation index	C/S T.011, Table 3.3
Downlink carrier frequency (long term)	C/S T.011, Table 3.3
Translation frequency	C/S T.011, Section 3.3
Wideband mode (relative to 406.05 MHz in) Location in baseband	
Narrowband mode (relative to 406.025 MHz in) Location in baseband	
Narrowband channel bandwidth (relative to 406.025 MHz centre frequency)	C/S T.011, Table 3.2
1 dB Bandwidth	
3 dB Bandwidth	
20 dB Bandwidth	
Wideband channel bandwidth (relative to 406.05 MHz centre frequency)	C/S T.011, Table 3.2
1 dB Bandwidth	
3 dB Bandwidth	
20 dB Bandwidth	
ALC dynamic range	C/S T.011, Table 3.2
Intermodulation Levels	C/S T.011, Table 3.3
Beacon signal Probability of Detecting Valid Messages	C/S T.009, Section 5.1

**Table C.2: INSAT Space Segment Assessment Indicators / Compliance Levels**

Assessment Indicator	Compliance Level Reference
EIRP in SAR channel	C/S T.011, Table 4.2
Spectral occupancy (of downlink)	C/S T.011, Figures 4.2a and 4.2b
G/T of 406 MHz receiver	C/S T.011, Table 4.2
Modulation index	C/S T.011, Table 4.2
Downlink carrier frequency Stability	C/S T.011, Table 4.2
Translation frequency stability Wideband mode (relative to 406.05 MHz in) Location in baseband Narrowband mode (relative to 406.025 MHz in) Location in baseband	C/S T.011, section 4.3
Narrowband channel 1 dB bandwidth (relative to 406.025 MHz)	C/S T.011, Table 4.2
Wideband channel 1 dB bandwidth (relative to 406.05 MHz)	C/S T.011, Table 4.2
ALC dynamic range	C/S T.011, Table 4.2
Beacon signal Probability of Detecting Valid Messages	C/S T.009, Section 5.1

**Table C.3: Electro-L Space Segment Assessment Indicators / Compliance Levels**

Assessment Indicator	Compliance Level Reference
EIRP in SAR channel	C/S T.011, Table 5.3
Spectral occupancy (of downlink)	C/S T.011, Figures 5.1a and 5.1b.
G/T of 406 MHz receiver	C/S T.011, Table 5.2
Downlink frequency with 406 MHz signal input	C/S T.011, Table 5.3
Translation frequency stability: long term One day 1.0 second	C/S T.011, Table 5.3
Channel bandwidth (3 dB relative to 406.05 MHz)	C/S T.011, Table 5.2
Beacon signal Probability of Detecting Valid Messages	C/S T.009, Section 5.1

**Table C.4: MSG Space Segment Assessment Indicators / Compliance Levels**

Assessment Indicator	Compliance Level Reference
EIRP in SAR channel	C/S T.011, Table 6.2
Spectral occupancy (of downlink)	C/S T.011, Figure 6.2a
G/T of 406 MHz receiver	C/S T.011, Table 6.2
Downlink carrier frequency (with 406.05 MHz in)	C/S T.011, Table 6.2
Translation frequency accuracy:	C/S T.011, Table 6.2
Channel bandwidth: 0.5 dB relative to 406.05 MHz Noise Equivalent bandwidth	C/S T.011, Table 6.2
Beacon signal Probability of Detecting Valid Messages	C/S T.009, Section 5.1

**Table C.5: MTG Space Segment Assessment Indicators / Compliance Levels**

Assessment Indicator	Compliance Level Reference
<i>EIRP in SAR channel</i>	<i>C/S T.011, Table 8.1</i>
<i>Spectral occupancy (of downlink)</i>	<i>C/S T.011, Figures 8.2 &amp; 8.3</i>
<i>G/T of 406 MHz receiver</i>	<i>C/S T.011, Table 8.1</i>
<i>Downlink carrier frequency (with 406.05 MHz in)</i>	<i>C/S T.011, Table 8.1</i>
<i>Translation frequency accuracy:</i>	<i>C/S T.011, Table 8.1</i>
<i>Channel bandwidth: 0.5 dB relative to 406.05 MHz Noise Equivalent bandwidth</i>	<i>C/S T.011, Table 8.1</i>
<i>Beacon signal Probability of Detecting Valid Messages</i>	<i>C/S T.009, Section 5.1</i>

- END OF ANNEX C -

**ANNEX D****GEOSAR IOC STATUS MESSAGE**

Should the test results confirm that the payload satisfies IOC requirements, the commissioning authority shall distribute the information identified in sections 1 and 2 below throughout the Cospas-Sarsat system using a SIT 605 message. Items not tested must be so noted as comments in the SIT 605 message.

**1.0 Test Results**

SPACECRAFT - _____		Date _____	
Test	Result	Pass / Fail	Comments
B.1 EIRP in SAR Channel			
B.2 Spectral Occupancy of the Downlink			
B.3 Spurious Output Levels			
B.4 G/T of 406 MHz Repeater			
B.5 Channel Bandwidth and Amplitude Ripple			
B.6 Downlink Carrier Frequency			
B.7 ALC Dynamic Range			
B.8 Modulation Index			
B.9 Translation Frequencies			
B.10 Intermodulation and Harmonic Levels			
B.11 Beacon Signal Processing			

Note: Graphics and supplementary data may be provided as attachments to this report and provided to the Cospas-Sarsat Secretariat for permanent retention.

## 2.0 IOC Mode

The spacecraft will be operated in the following IOC mode.

Channel Bandwidth	WB or NB
ALC	ON or Off

Operational Limitations:

Commissioning Authority: \_\_\_\_\_ Date: \_\_\_\_\_

- END OF ANNEX D -

**ANNEX E****GEOSAR COMMISSIONING REPORT**

Should the test results confirm that the GEOSAR payload satisfies commissioning requirements, the commissioning authority shall distribute the information contained in the commissioning report as identified below throughout the Cospas-Sarsat system using a SIT 605 message.

Satellite: _____		Date _____	
Configuration	Pass/Fail*	Operational, Limited Operation, Not Operational	Comments
NB/Fixed gain			
NB/ALC On			
WB/Fixed gain			
WB/ALC On			

Payload Status: FOC or LOC

Initial operational configuration:

The spacecraft will initially be operated in the following mode:

Channel Bandwidth	WB or NB
ALC	ON or Off

Operational Limitations:

Other Remarks:

Commissioning Authority: \_\_\_\_\_ Date: \_\_\_\_\_

-END OF ANNEX E-

- END OF DOCUMENT -



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