
SATCOM
WITH
ARC
Application
in
Search and Rescue Operations Planning

# Goal

Coverage evaluation of COSPAS-SARSAT Emergency Service

- Will my emergency beacon be heard and will I be rescued?

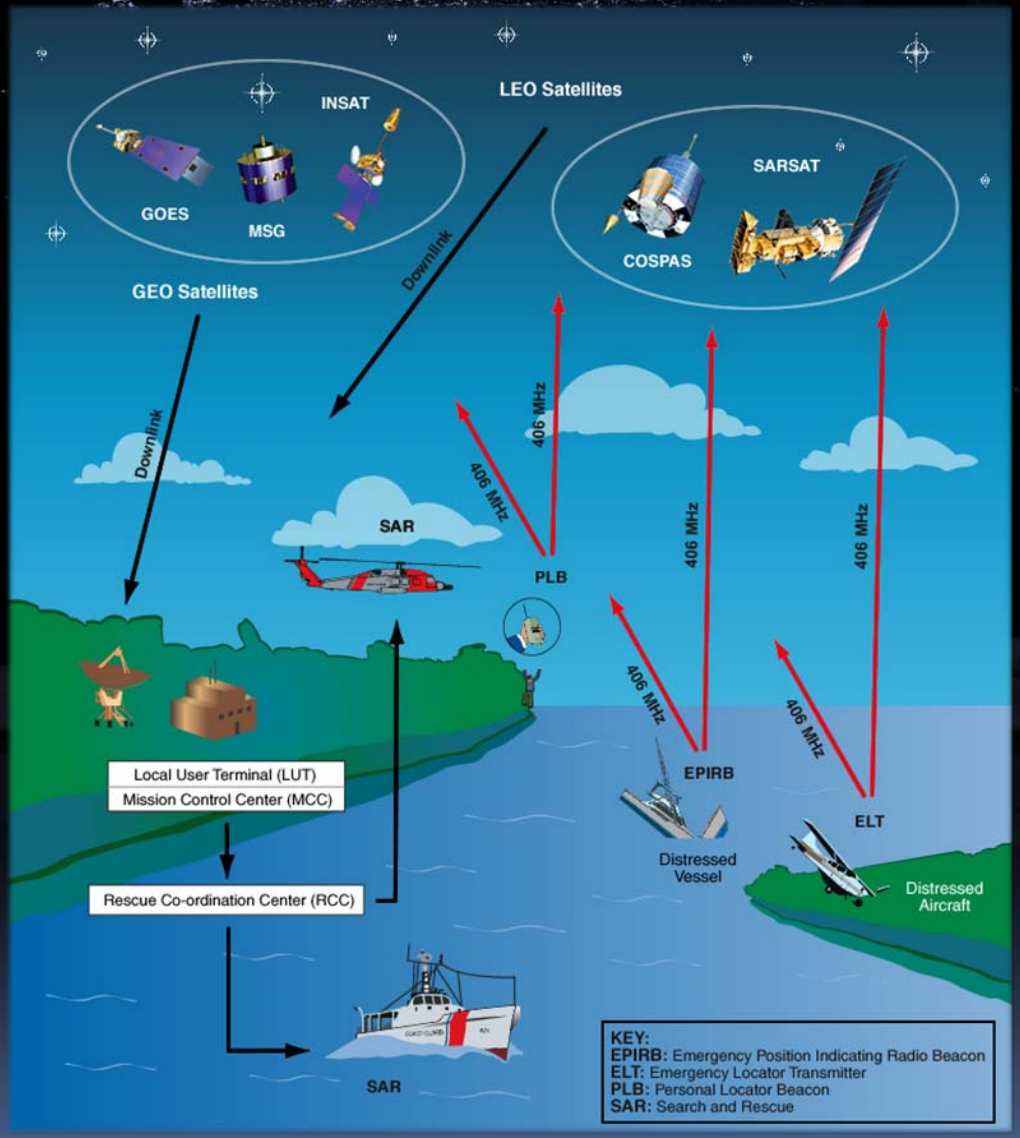
We will discuss:

- COSPAS-SARSAT system
- Satellite Link Analysis
- Arc Demo
- Discussion

# COSPAS-SARSAT

When an incident occurs:

- Distress Beacons are activated
- Satellites listen for and relay information to Ground Terminals
- Mission Control Centers dispatch SAR services to incident location



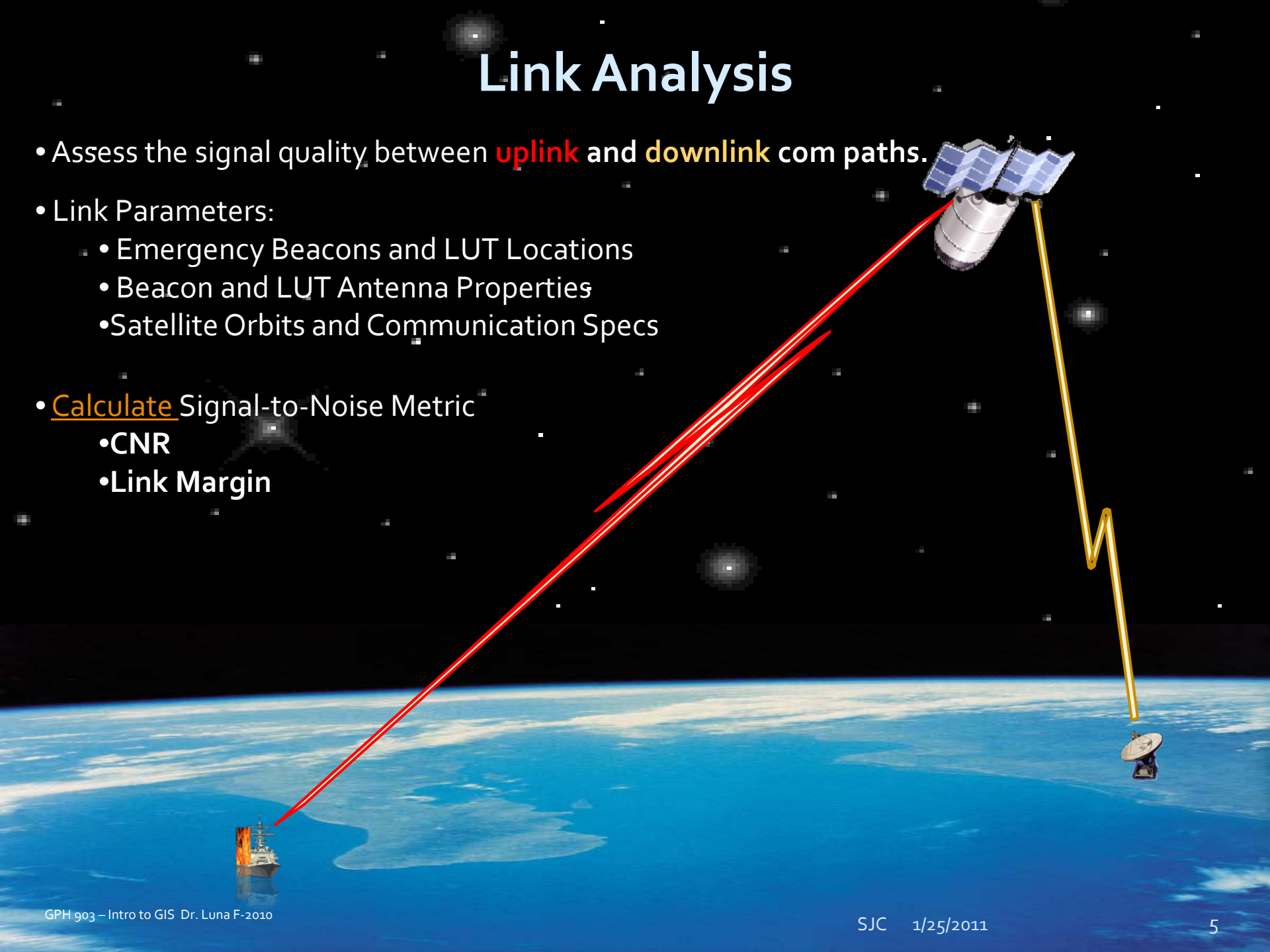

System Overview ➲

# COSPAS-SARSAT
## Satellites

| Orbit | Altitude (1000 km) | Motion | Operational |
|---|---|---|---|
| GEO<br>Geostationary Earth Orbit | 36 | Fixed Relative to Earth | 5 |
| LEO<br>Low Earth Orbit | 0.85 (NOAA)<br>1 (COSPAS) | Passes along Poles | 6 |

# Link Analysis

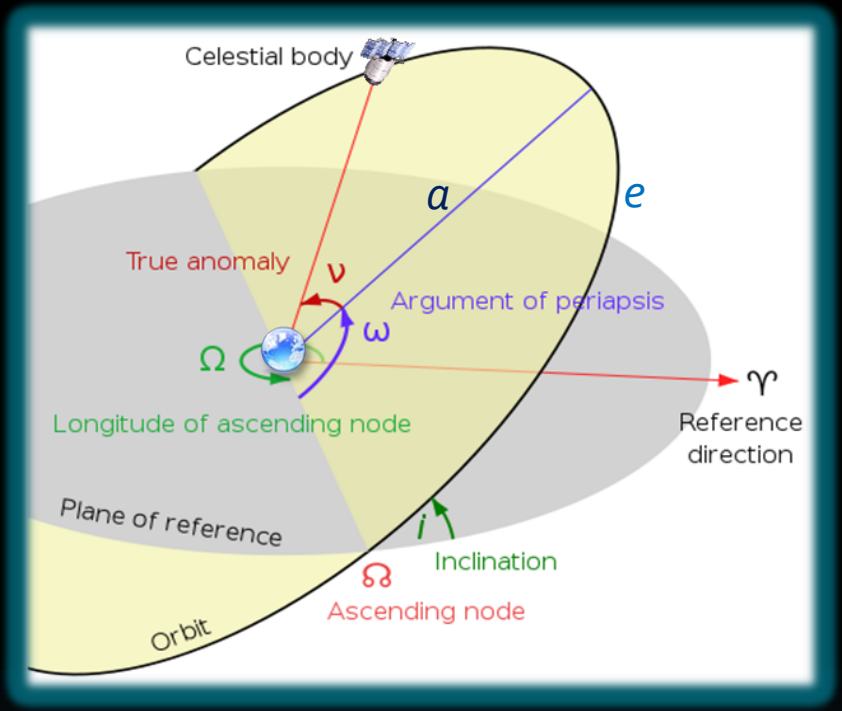
- Assess the signal quality between **uplink** and **downlink** com paths.
- Link Parameters:
  - Emergency Beacons and LUT Locations
  - Beacon and LUT Antenna Properties
  - Satellite Orbits and Communication Specs
- Calculate Signal-to-Noise Metric
  - **CNR**
  - **Link Margin**



# Satellite Two-Line Element Set

- Defines an initial state vector used in NORAD's propagator (SGP4)

| Celestial Orbital Elements | Line | Symbol |
|---|---|---|
| Inclination | 2 | $i$ |
| Right Ascension of Ascending Node | 2 | $\Omega$ |
| Eccentricity | 2 | $e$ |
| Argument of Perigee | 2 | $\omega$ |
| Mean Anomaly | 2 | - |
| Semi-major Axis | - | $a$ |

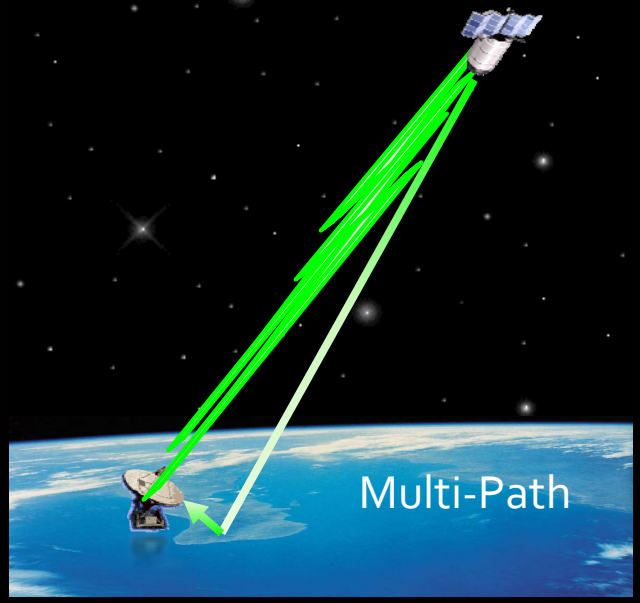



```
ISS (ZARYA)
1 25544U 98067A 08264.51782528 -.00002182 00000-0 -11606-4 0 292 7
2 25544 51.6416 247.4627 0006703 130.5360 325.0288 15.72125391 56353 7
```

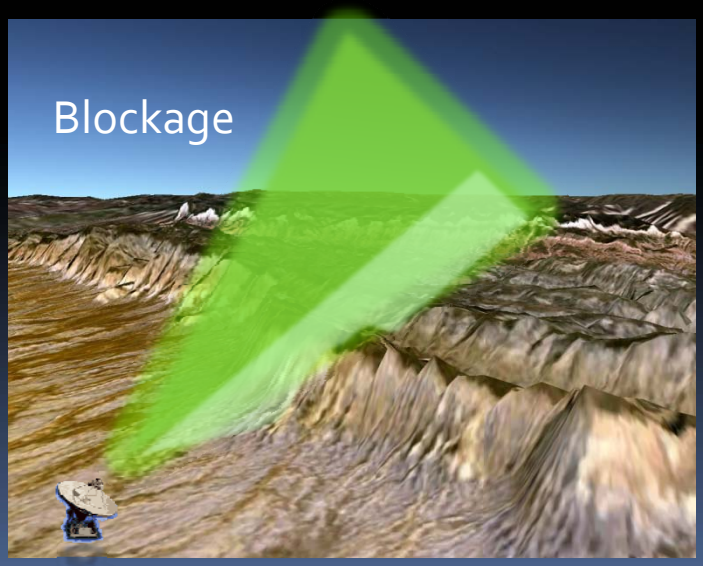
# Emergency Beacons

- Send to and Receive from Satellites
- Ground Transmitters and Receivers require
  - Geographic location
  - Power
  - Antenna Gain
  - Noise Characteristics

# Environmental Losses









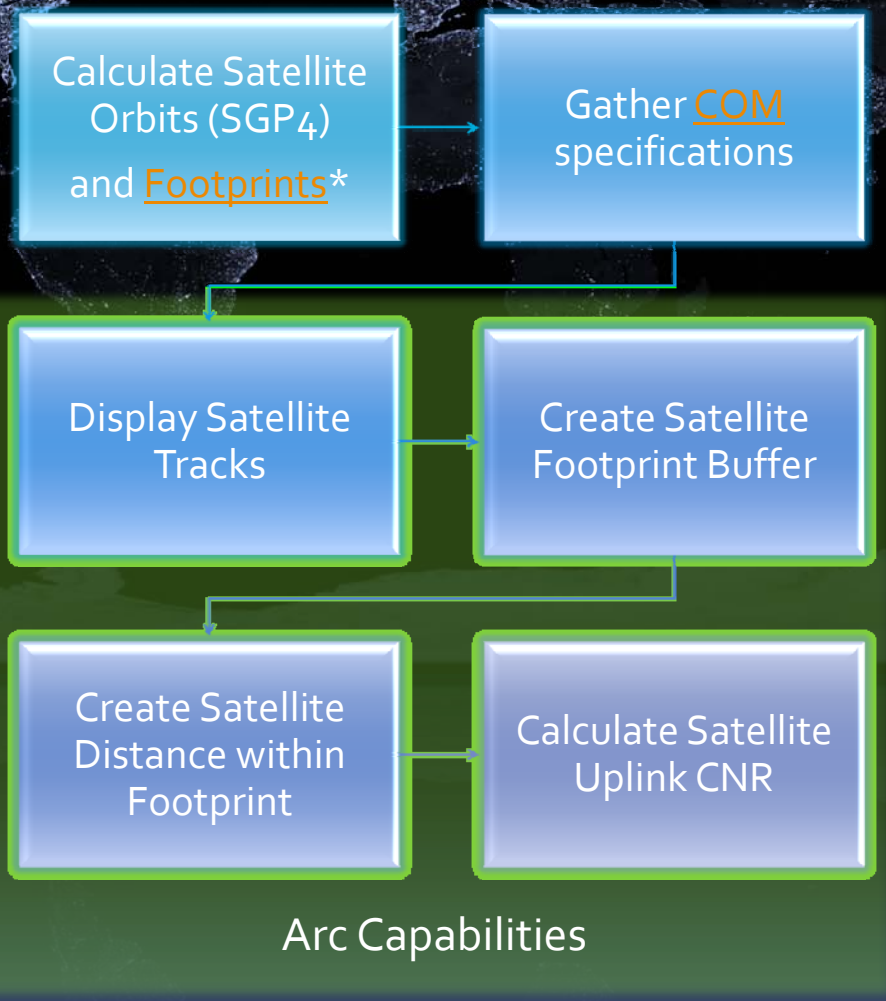
Impair Signal Quality

# Arc Demo

- Satellite Tracks
- Satellite Coverage Area
- Signal Quality Assessments

- Baseline
  - 2D Flat Earth Surface
  - "Clear Sky" Conditions
  - Clean Line-of-Sight (LOS)

# Work Flow

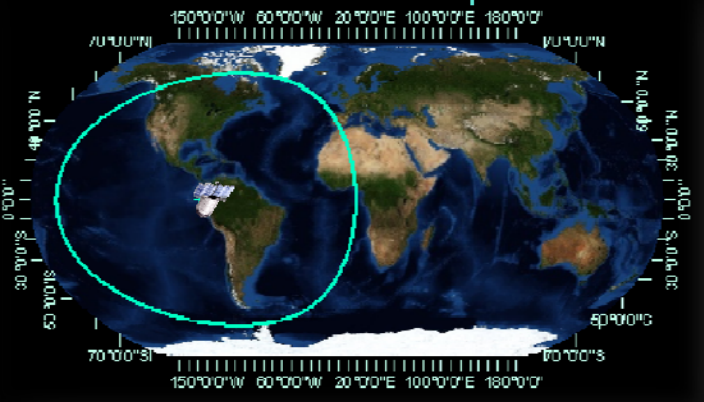



* Matlab Scripts Implementations

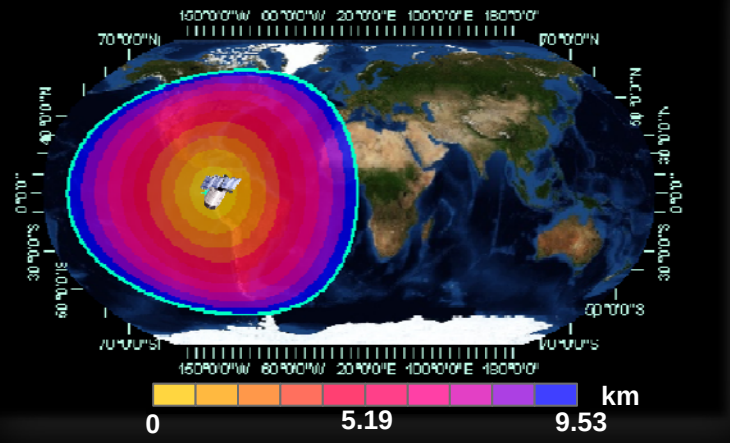
# Arc Demo

## GOES-13 @ 80° W

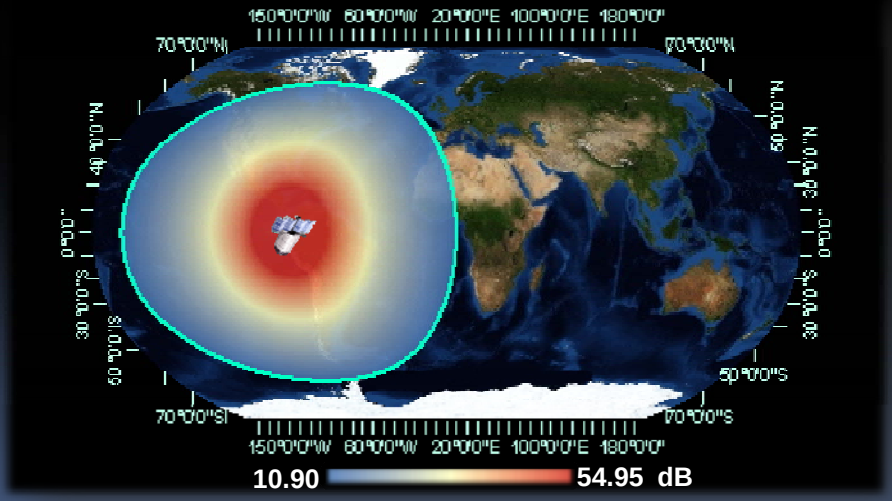
### Maximum Footprint



### Distance Raster



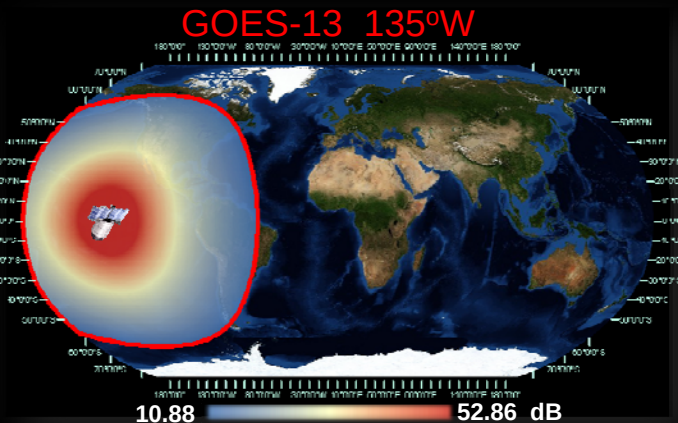

### Uplink CNR

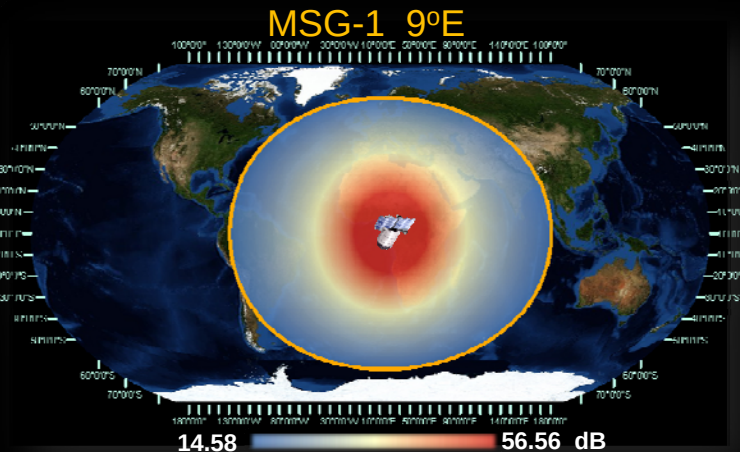


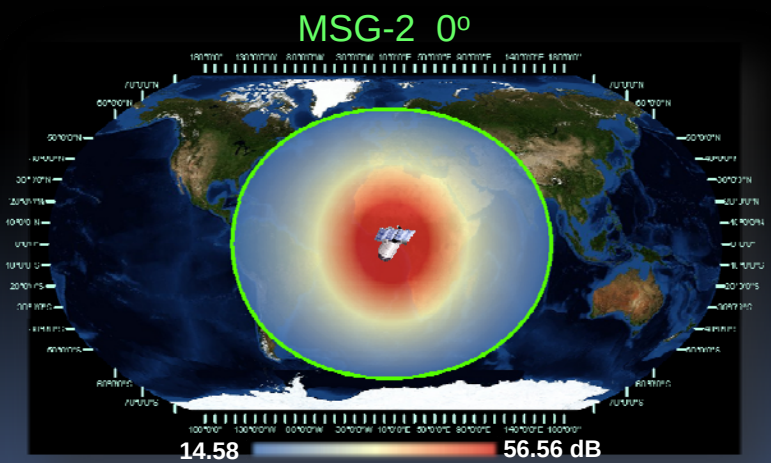

- Signal above Noise Floor (-154 dB)
- Satellite will hear Beacons within its Footprint
- GEO Satellites have similar CNR levels within their Footprints

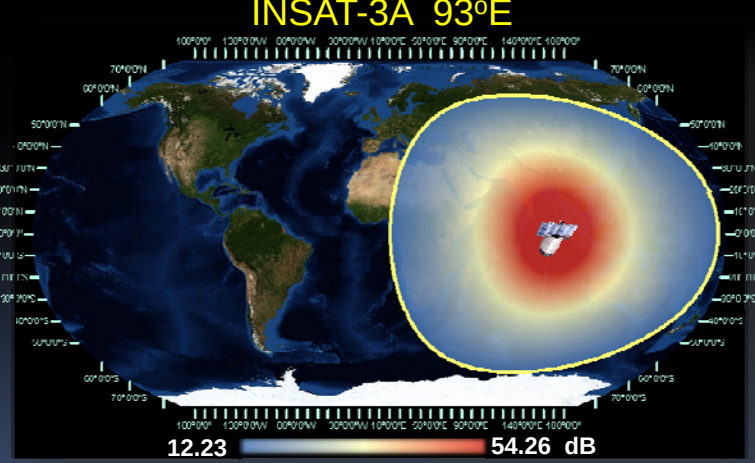
WGS-84 Datum
Robinson Projection

# Arc Demo
## GEOSAR Uplink CNR



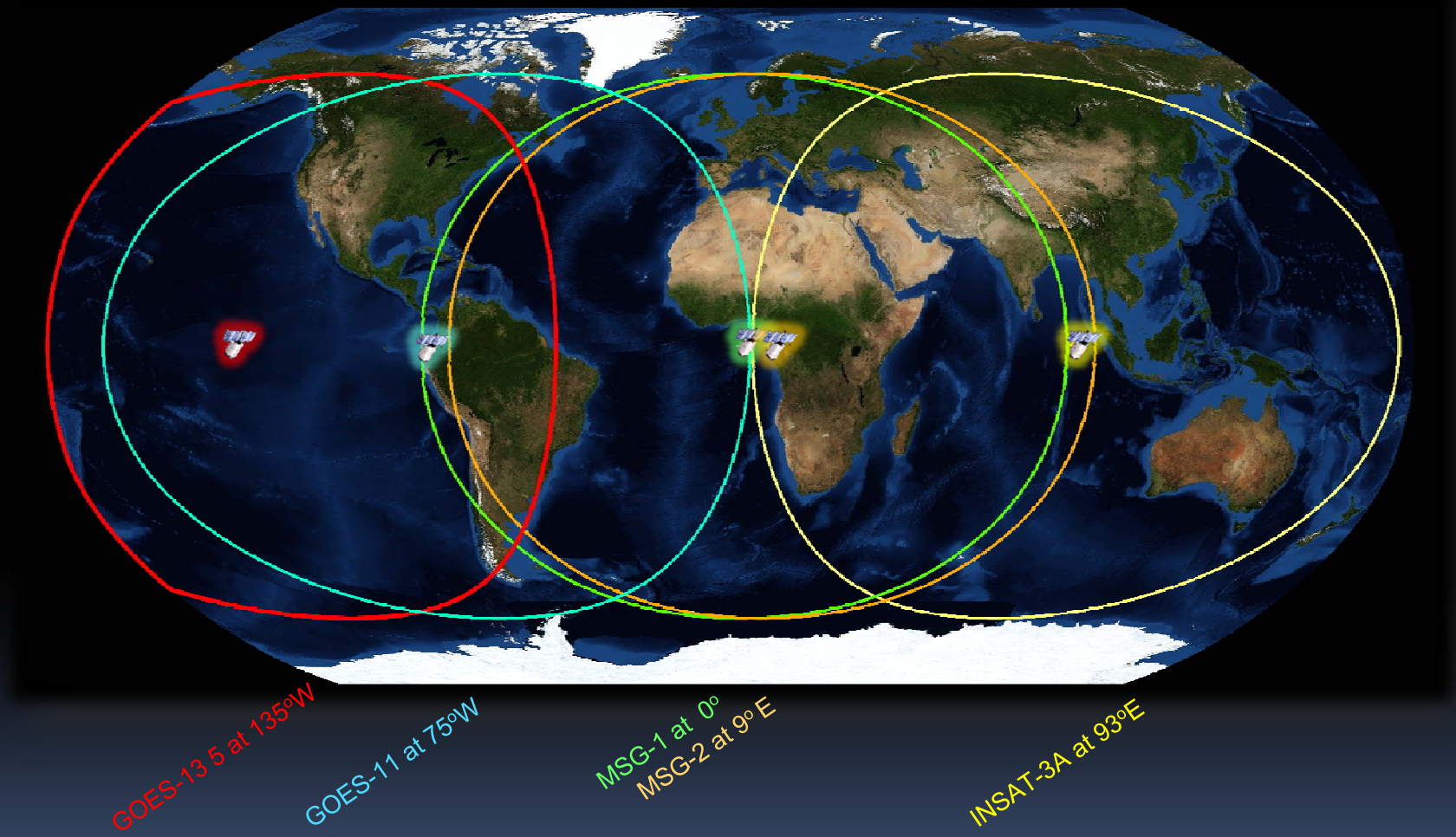



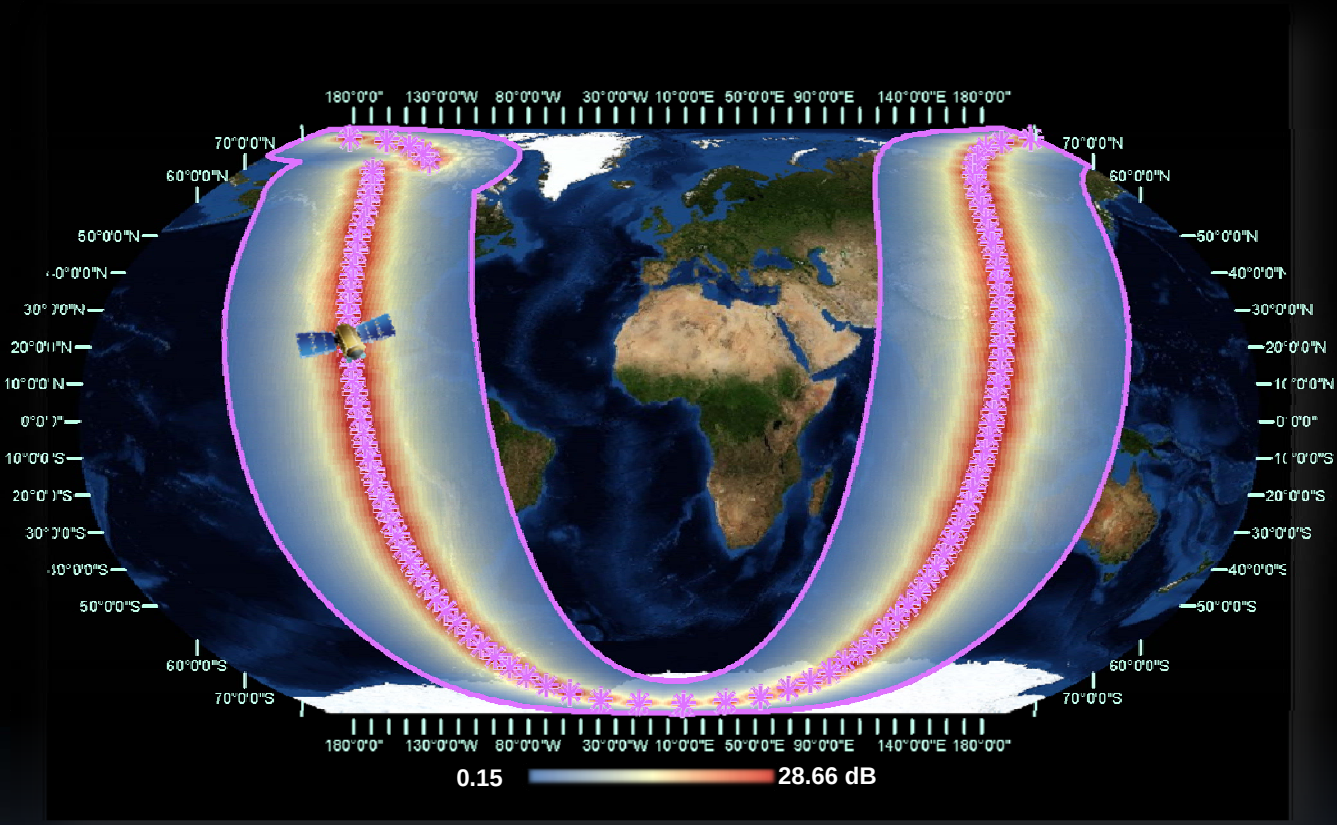
# Arc Demo

GEO Satellite Footprints provides Global Coverage



# Arc Demo

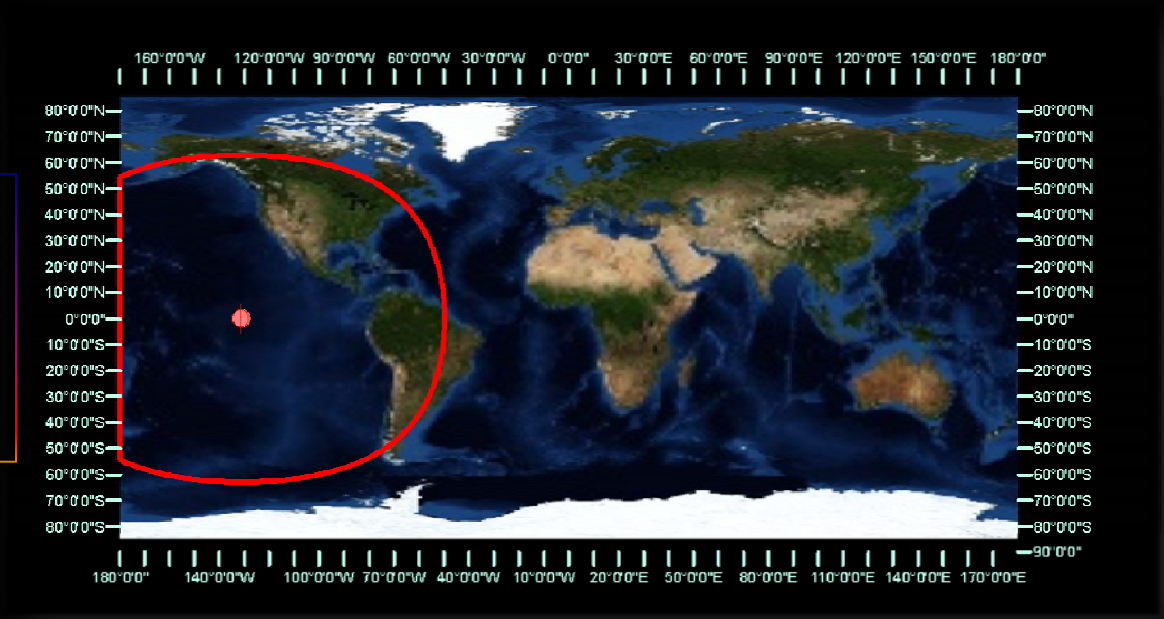
## NOAA-16




- Signal above Noise Floor (-154 dB)
- Single Pass Coverage of Poles (1-pass ~ 100 min)
- Each satellite pass covers a swath of each surface

# ArcGIS Anomaly

Arc Buffer does not cross over international date-line (180º)





- Limits GOES-11 Coverage Area
- Impacts Distance and CNR Calculations
- Solution unknown and pending investigation

- Suggestions are welcomed

# Summary

- **COSPAS-SARSAT Global Search and Rescue Service**
- **Link Analysis provides a quantitative assessment of system performance**
- **Demonstrated Satellite viewing areas and signal quality within coverage.**

Obstacles
- Shown an Arc anomaly with calculating distances crossing date-line.

Future Work could incorporate:

- DEM illustrating terrain
- Atmospheric and Cloud Cover Models
- Wave heights

can be used to assess the impact of signal quality and coverage visibility.

# References

## Text Books


- Agrawal, Varsha et. al. *Satellite Technology: Principles and Applications*. 1st ed. NJ, Wiley & Sons. © 2007


## Reports


- Cospas-Sarsat Technical Documentation
- C/S T.011 Is.1 Rv.6 Oct-2010
  - *Description of the 406 MHz Payloads used in the COSPAS-SARSAT GOESAR System*
- C/S T.003 Is.4 Rv.1 Oct-2010
  - *Description of the Payloads used in the COSPAS-SARSAT GOESAR System*
- C/S T.001 Is.3 Rv.10 Oct-2009
  - *Specification for COSPAS-SARSAT 406 MHz Distress Beacons*
- Hoots, Felix et. al. *Spacetrack No.3 Models for Propagation of NORAD element sets.* VA DOD documentation center 1988


## Websites

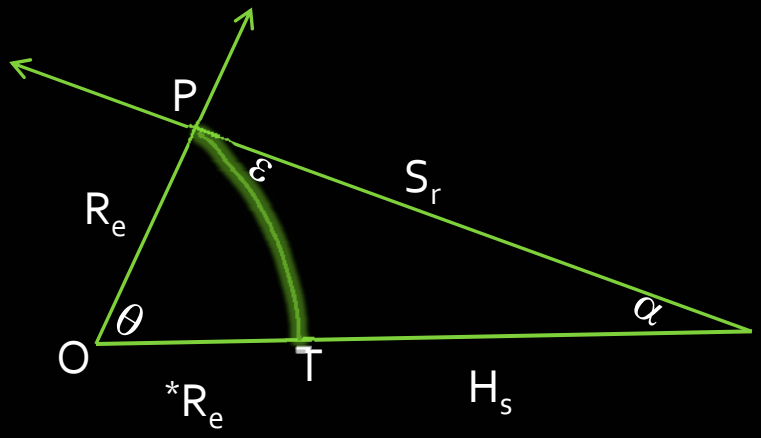
- NORAD TLE sets: *www.tle.info*
- COSPAS-SARSAT *www.cospas-sarsat.org*

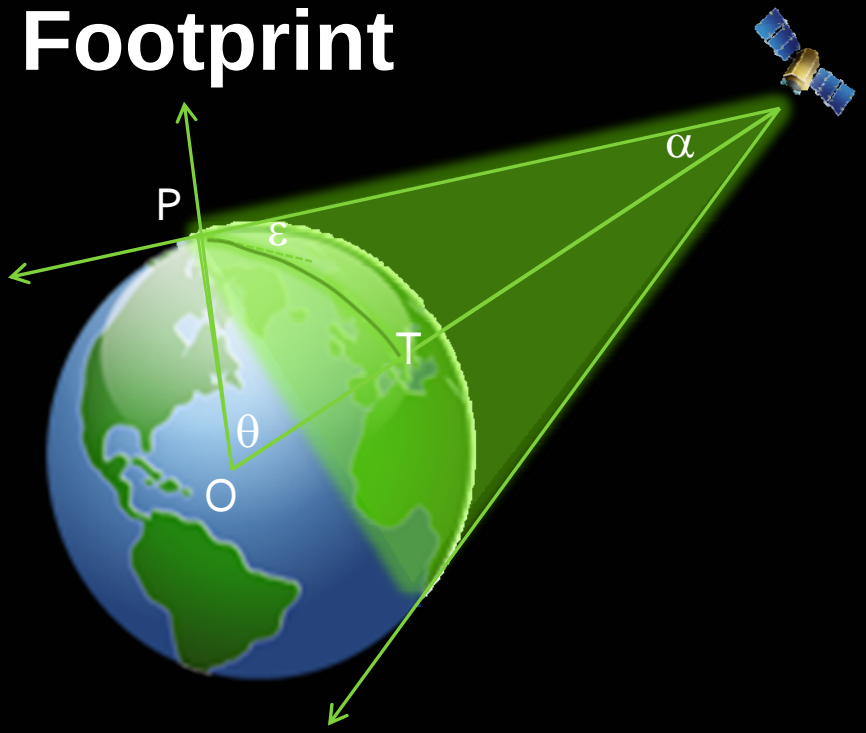
# Discussion


Thank You
for
Your Time ;-)

# Backup Slides

# Satellite Footprint




Coverage Angle $\alpha = \sin^{-1}(R_e/R_e + H_s) \cos \varepsilon$ Max @ $\varepsilon = 0$

Earth Center Angle $\theta = 90^0 - \alpha - \varepsilon$

Satellite Ground Track @ T

Max Footprint @ P = ($T_{lon} + \alpha$, $T_{lat}$)

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* $R_e$ = Radius of Earth ~6378 km

# Signal-Noise Calculations

- **CNR :** Carrier-Noise Power Ratio

  EIRP – Path Losses - $L_{misc}$ + $G/T$ + $k_{dB}$ - 10log$B$

- **$E_BN_O$:** Energy-Bit Noise Ratio

  CNR + $10\log_{10}(B_R)$ – $10\log_{10}(BER)$

- **Link Margin**

  CNR – Noise Threshold

- **Receiver's Noise Power (dB)**

  $10\ \mathrm{Log}_{10}(kT_sB_r)$

- **Received Power (dB)**

  EIRP – Path Losses

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# Link Parameters

| Satellite Parameters (Uplink) | | GOES Series | MSG Series | INSAT-3A | NOAA-16 |
|---|---|---|---|---|---|
| Frequency | (MHz) | 406.05 | 406.05 | 406.05 | 406.05 |
| Receiver Gain | (dBi) | 9.9 | 3.45 | 11.0 | -4 – 6 |
| Receiver (G/T) | (dB/K) | -17.6 | -21.3 | -19.0 | -0.011 – 1.017 |
| Receiver Bandwidth | (kHz) | 80 | 80 | 80 | 80 |
| Nominal Input Level | (dBm) | -173.0 | -176.9 | -173.1 | -143 |
| System Noise Temp | (K) | 359 | 301 | 300 | 350 |
| Receiver Noise Floor | (dBK) | -154.02 | -154.78 | -154.80 | -154.13 |

| Beacon Uplink Parameters | | |
|---|---|---|
| Frequency | (MHz) | 406.05 |
| Power | (W) | 3 |
| EIRP | (dB) | 30 |
| Gain | (dBi) | -3.0 |
| Bandwidth | (kHz) | 80 |
| Bit Rate | (bps) | 400 |

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# Frequency Bands

| Letter Designation | Frequency (GHz) |
|---|---|
| L | 1 -2 |
| S | 2 -4 |
| C | 4 – 8 |
| X | 8 – 12 |
| Ku | 12 -18 |
| K | 18 - 27 |
| Ka | 27 – 40 |
| O | 40 -50 |
| V | 50 – 75 |

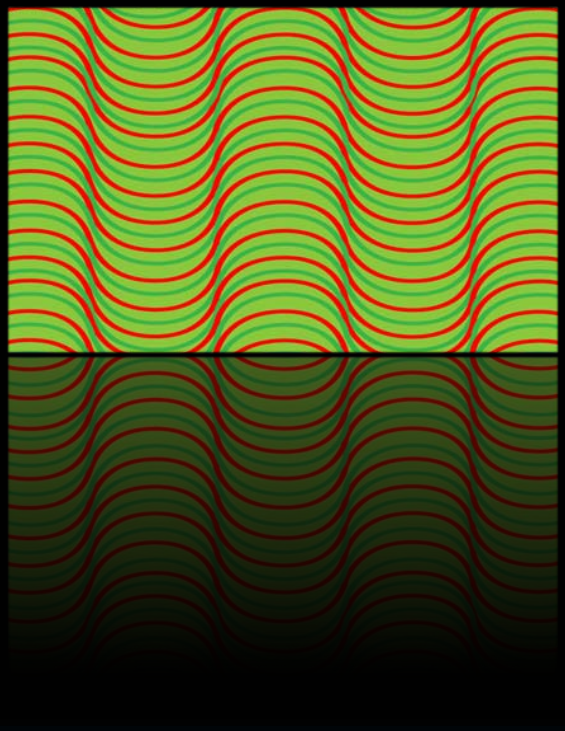
*Source: www.radio-electronics.com*

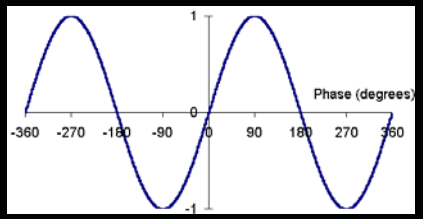
# Bandwidth

- *Defines the Frequency Range Messages are transmitted and/or Received*

- *Messages are modulated waves of radiation that carry encoded information.*

- *Modulation Schemes define how message words are constructed .*





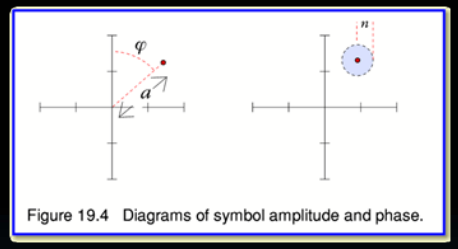



Figure 19.4 Diagrams of symbol amplitude and phase.

$$S\{t\} \equiv a\ \mathrm{Sin}\{2\pi f t\} + b\ \mathrm{Cos}\{2\pi f t\}$$

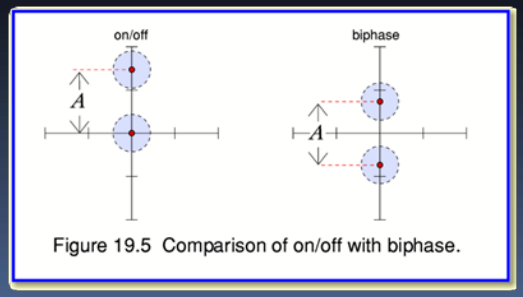


Figure 19.5 Comparison of on/off with biphase.

| | 00 | 10 | 01 | 11 |
|---|---|---|---|---|
| a | -A/2 | A/2 | -A/2 | A/2 |
| b | -A/2 | -A/2 | A/2 | A/2 |

# System Overview

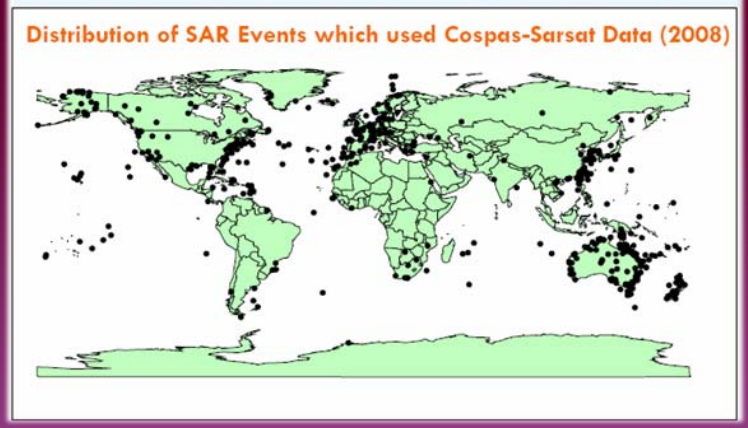
## Cospas-Sarsat System Status

As at February 2010, the Cospas-Sarsat System comprised:

- 6 LEOSAR satellites in low-altitude polar orbits;
- 5 GEOSAR satellites;
- 55 LUTs receiving signals transmitted by LEOSAR satellites;
- 21 LUTs receiving signals transmitted by GEOSAR satellites;
- 30 Mission Control Centres for distributing distress alerts to SAR services; and
- More than 900,000 406 MHz beacons.


## System Use Statistics

The figures below show the distribution of 2008 SAR events assisted by Cospas-Sarsat data and the evolution of use of the System since 1999. Since the beginning of its operation in September 1982 through the end of 2008, Cospas-Sarsat provided alerts that assisted in the rescue of almost 27,000 persons in about 7,300 SAR events.

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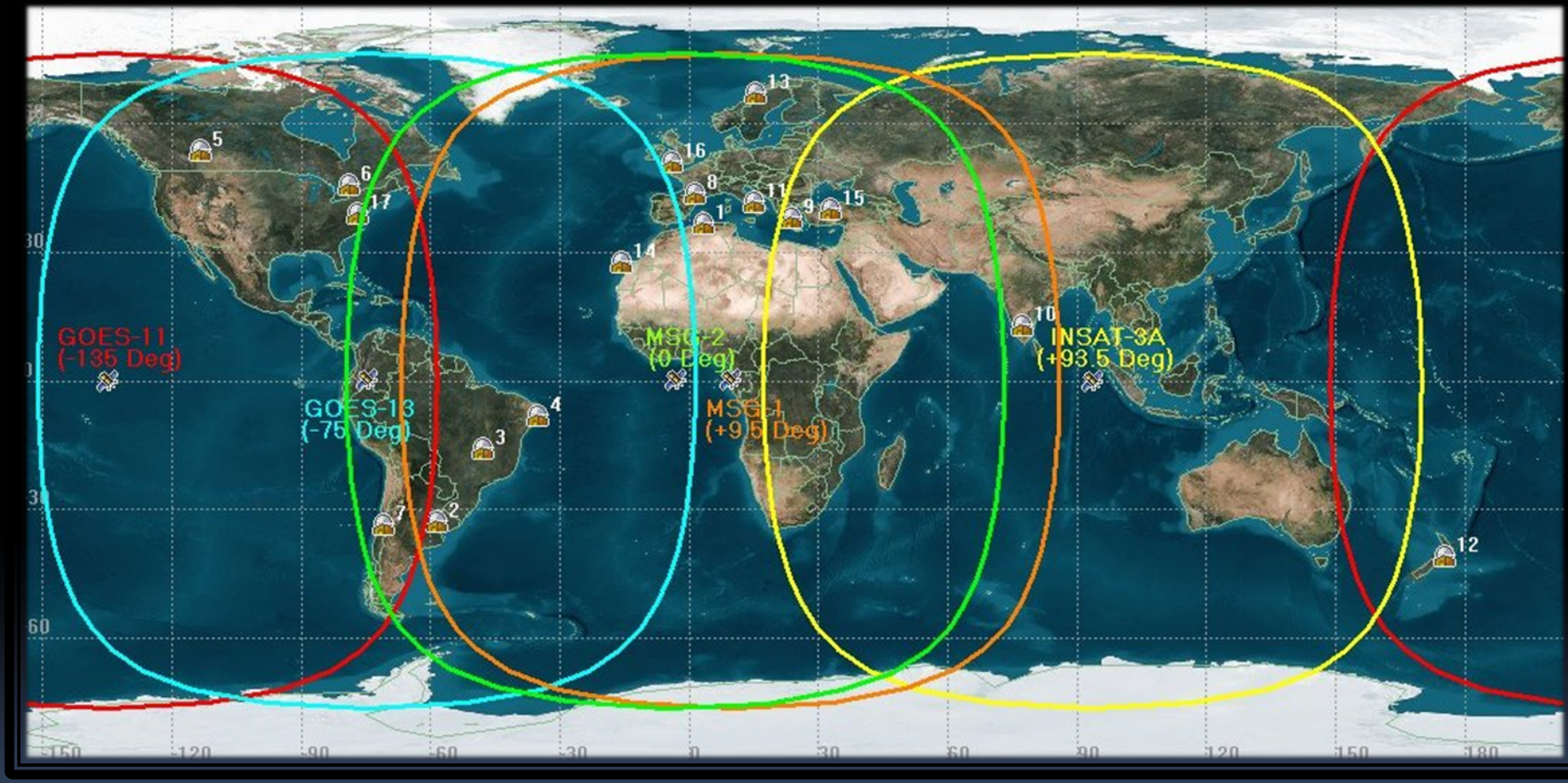
*Source: www.cospas-sarsat.org*

# COSPAS-SARSAT
## GEO System Locations




*Source: www.cospas-sarsat.org*

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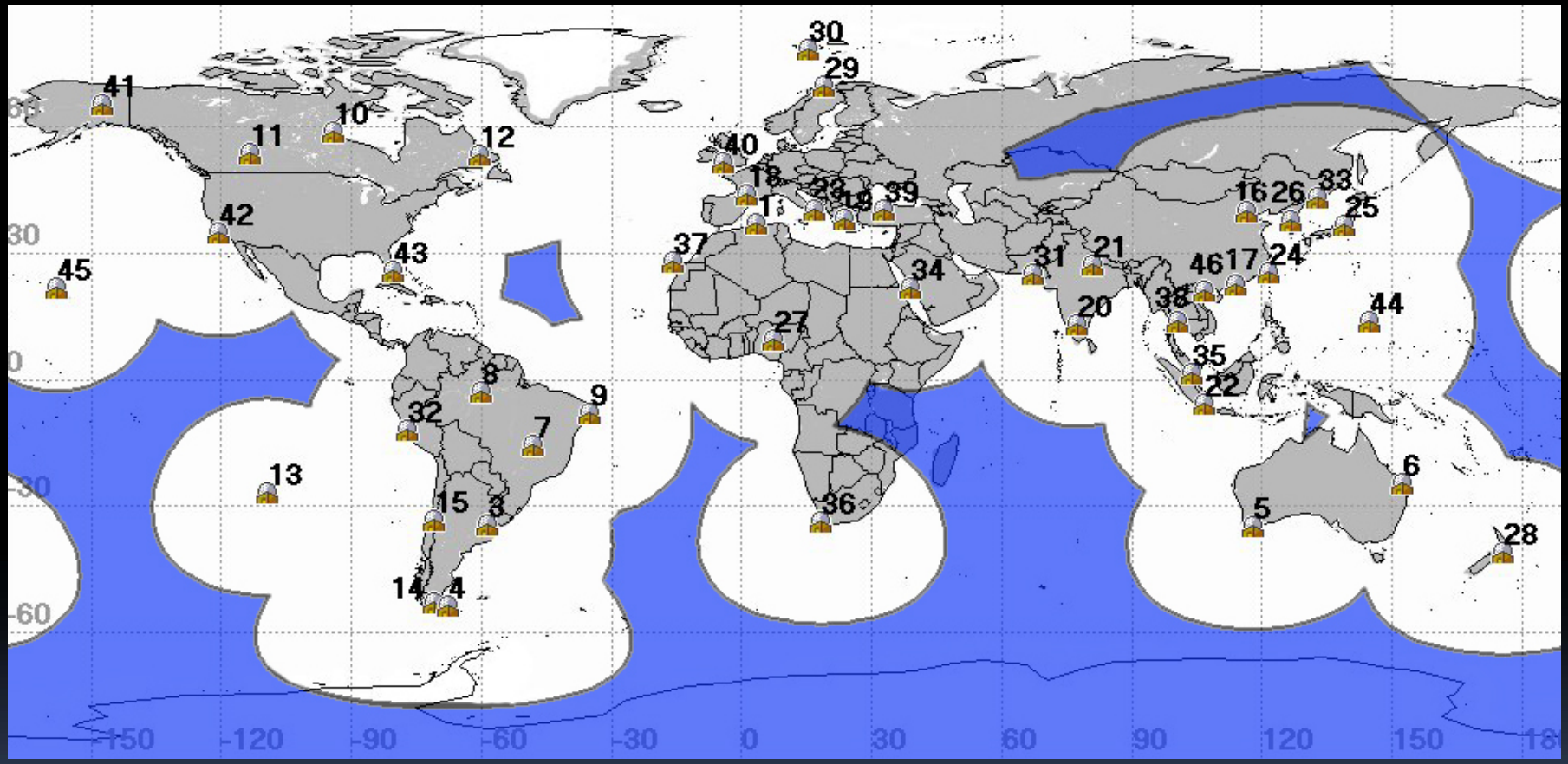
# COSPAS-SARSAT
## LEO System Locations




*Source: www.cospas-sarsat.org*

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