SARSAT Overview

SAR Controllers Workshop 2017
February 27 - March 2, 2017
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NOAA
SARSAT Satellite Systems Engineer

Agenda

- Importance of SARSAT
- Cospas-Sarsat
- System Description
  - User Segment (Beacons)
  - Space Segment
  - Ground Segment
  - Search and Rescue (SAR) Segment
- U.S. SARSAT
- SARSAT Challenges

SARSAT Authorities

- International Cospas-Sarsat Programme Agreement
  - Intergovernmental agreement that assures the long term operation of the system on a non-discriminatory basis and supports ICAO and IMO, signed by Russia, France, Canada and United States
- Interagency Memorandum of Agreement for the United States Satellite-Aided Search and Rescue System
  - Interagency agreement addressing the management and operation of the U.S. Cospas-Sarsat System and the development and implementation of SAR/GPS
- National Regulations
  - Public Law 91-596, 106-181: Federal Aviation Act that requires general aviation (GA) aircraft to carry ELTs
  - Title 46 of the CFR 406 MHz EPIRBs, and Title 14, Subpart 91.207 deals with the carriage of 406 MHz ELTs.
  - The FCC authorizes the use of the 406 MHz frequency for EPIRBs CFR Title 47, Part 80, ELTs CFR Title 47, Part 87, and PLBs in CFR Title 47, Part 95.
  - State of Hawaii law requires all boats operating more than a mile off-shore to carry either an EPIRB or a Very High Frequency (VHF) radio.
- International Regulations
  - ICAO was founded through the Convention on International Civil Aviation signed on 7 December 1944. It is the United Nations Specialized Agency responsible for international civil aviation operations. ICAO requires the carriage of 406 MHz ELTs on certain international flights that fall under the ICAO Convention. Specifically, Annexes 6, 10, and 12 to the Convention on International Civil Aviation requires carriage and registration of 406 MHz emergency beacons. The United States is a Party to this Convention.
  - IMO is the United Nations' specialized agency responsible for improving maritime safety. IMO, through the Global Maritime Distress and Safety System (GMDSS), requires the carriage of EPIRBs for vessels that fall under the International Convention for the Safety of Life at Sea (SOLAS) Convention. Specifically, IMO resolutions A.662(16), A.694(17), A.696(17), A.810(19), and A.887(21) deal with carriage requirements, standards, type approval and registration of emergency beacons. The United States is a Party to the SOLAS Convention.
  - The International Telecommunication Union (ITU) has allocated the 406 MHz frequency band for the exclusive use of low-power, earth-to-space EPIRBs (International Radio Regulation No. 2997A)

Cospas-Sarsat Overview

- **COSPAS:** Cosmicheskaya Systyema Poiska Aariynyich Sudov (Russian) which translates loosely "Space System for the Search of Vessels in Distress"

- **SARSAT:** Search And Rescue Satellite Aided Tracking

Cospas-Sarsat provides, free-of-charge, distress alert and location information to search and rescue authorities anywhere in the world for maritime, aviation and land users in distress.

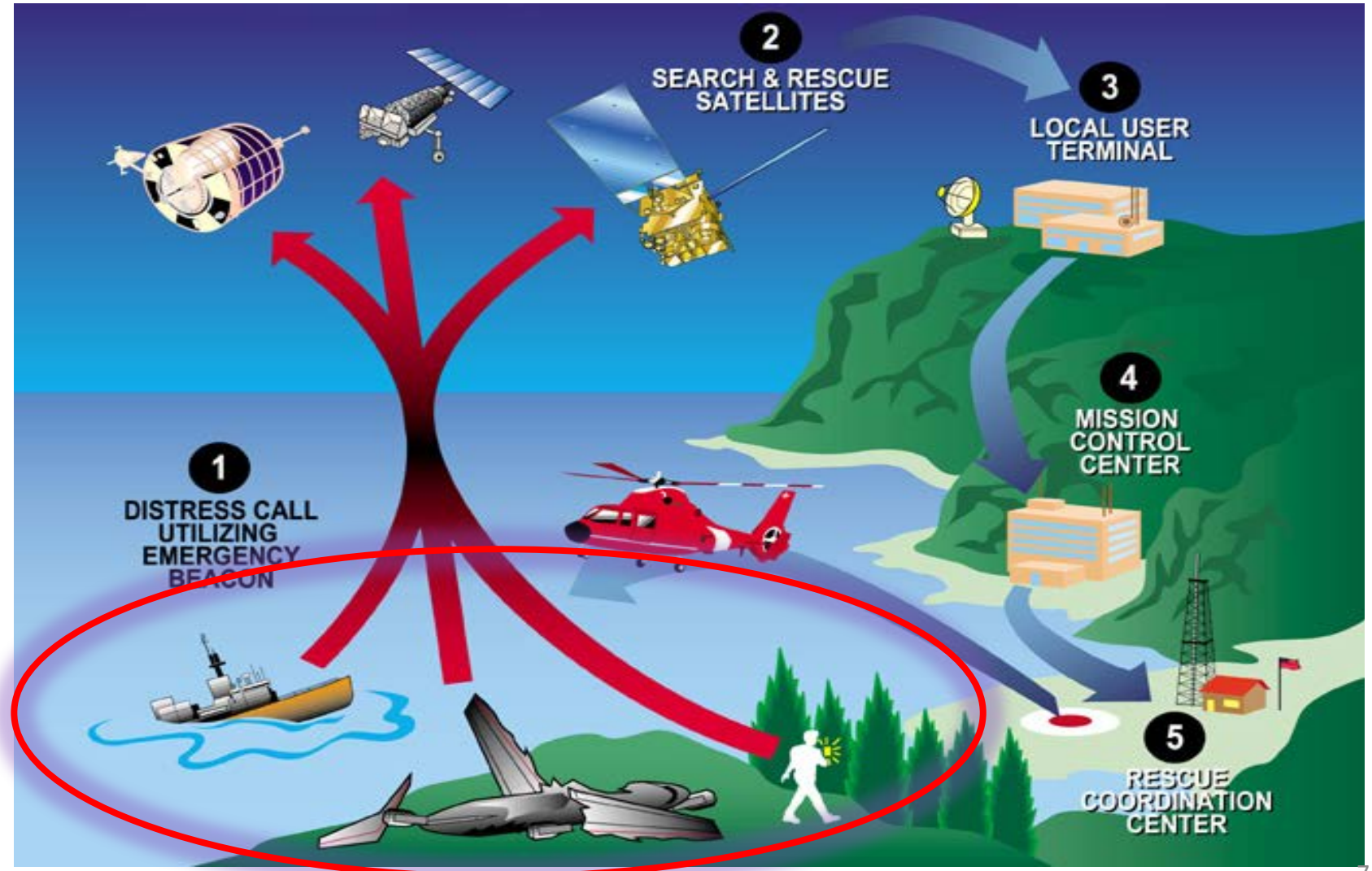
Cospas-Sarsat takes the "search" out of Search and Rescue

Cospas-Sarsat Summary

- 4 Parties to the Cospas-Sarsat Agreement
- 26 Ground Segment Providers
- 11 User States
- 2 Participating Organizations
- Space Segment
  - 5 Low Earth Orbit Search and Rescue Satellites
  - 6 Operational Geostationary Search and Rescue Satllites
- Ground Segment
  - 31 Mission Control Centers (MCCs)
  - 58 Low Earth Orbit Local User Terminals (LEOLUTs)
  - 22 Geostationary Local User Terminals (GEOLUTs)
- Over 1,200,000 Beacons

Cospas-Sarsat Participants

Cospas-Sarsat System Overview
User Segment



User Segment – Beacons

Activation:

- **Manual**
- **Automatic (Hydrostatic/G-Switch)**

Signal:

- **406 MHz (Digital)**
- **121.5 MHz (Analog) Homing**
- **Applications:**
- **Maritime - Emergency Position-Indicating Radio Beacon (EPIRB)**
- **Aviation - Emergency Locator Transmitter (ELT)**
- **Personal/Land - Personal Locator Beacon (PLB)**
- **Security – Ship Security Alerting System (SSAS)**

*** Most U.S. general aviation ELTs are still 121.5 MHz which are no longer monitored by Cospas-Sarsat**

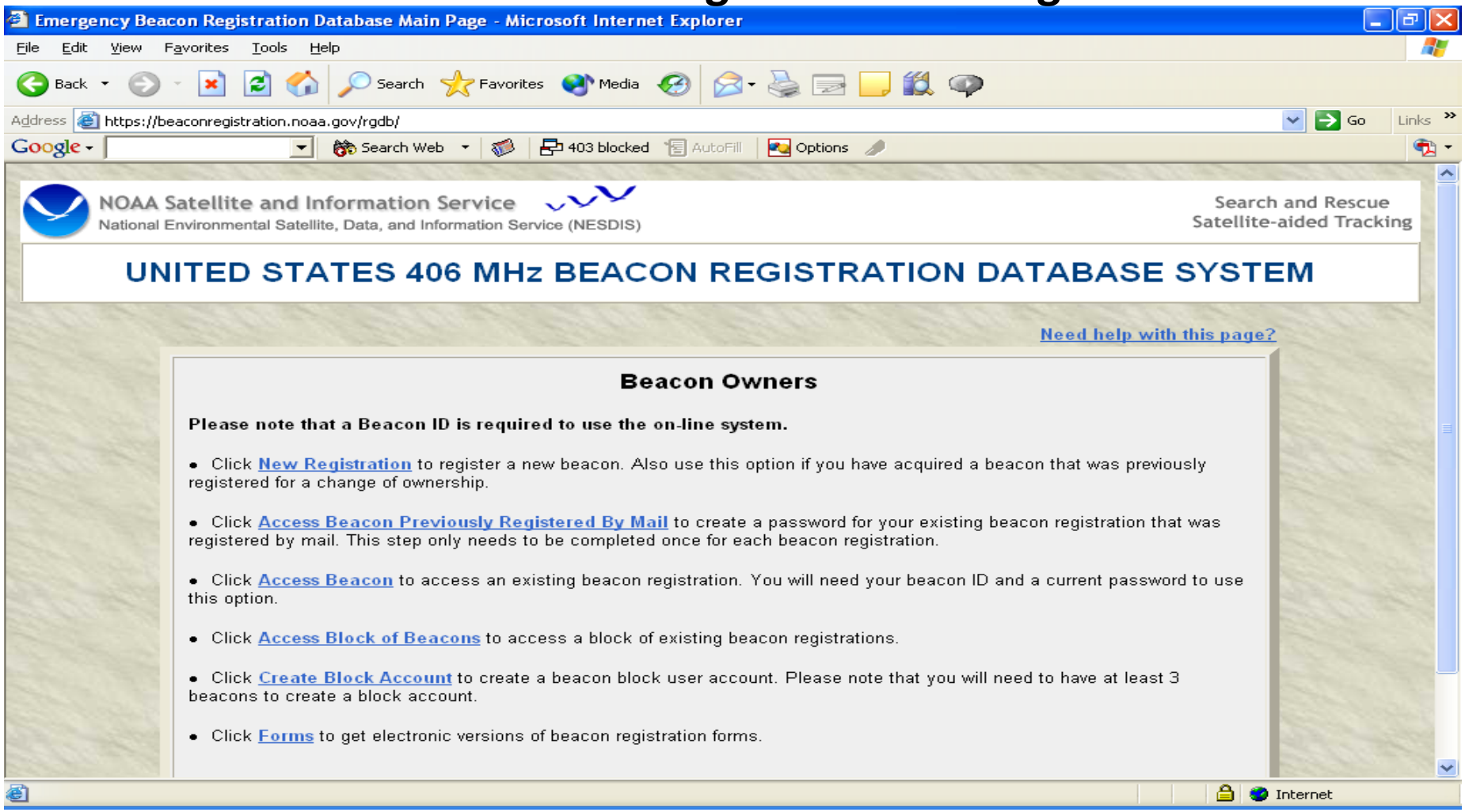
User Segment

Attributes of 406 MHz

- Every beacon has unique 15 digit hex identification
  - Unique ID allows registration with contact information
  - Non-Distress activations can be terminated with a phone call
  - Reduces stress on SAR assets
- Powerful 5 watt transmitter and digital signal increases accuracy of location by Doppler processing
- The system can discriminate between real beacon transmissions and non-beacon transmissions which reduces the resources spent on tracking interfering sources
- Global coverage provided by store and forward capability of Cospas-Sarsat LEOSAR satellites
- Increased system capacity due to short duration transmission, and spreading of frequency allocation

User Segment – Beacon Registration

www.beaconregistration.noaa.gov



Importance of Registration

Identification

- Digital data transmitted by beacon provides nationality and type of beacon
- Tail number or other identifying information can be encoded into the beacon
- Registration Database provides additional information such as owner/operator, and can include specifics on aircraft or vessel
- In most cases, false alerts are resolved prior to launch of resources, saving taxpayer $$

Importance of Registration

Detection

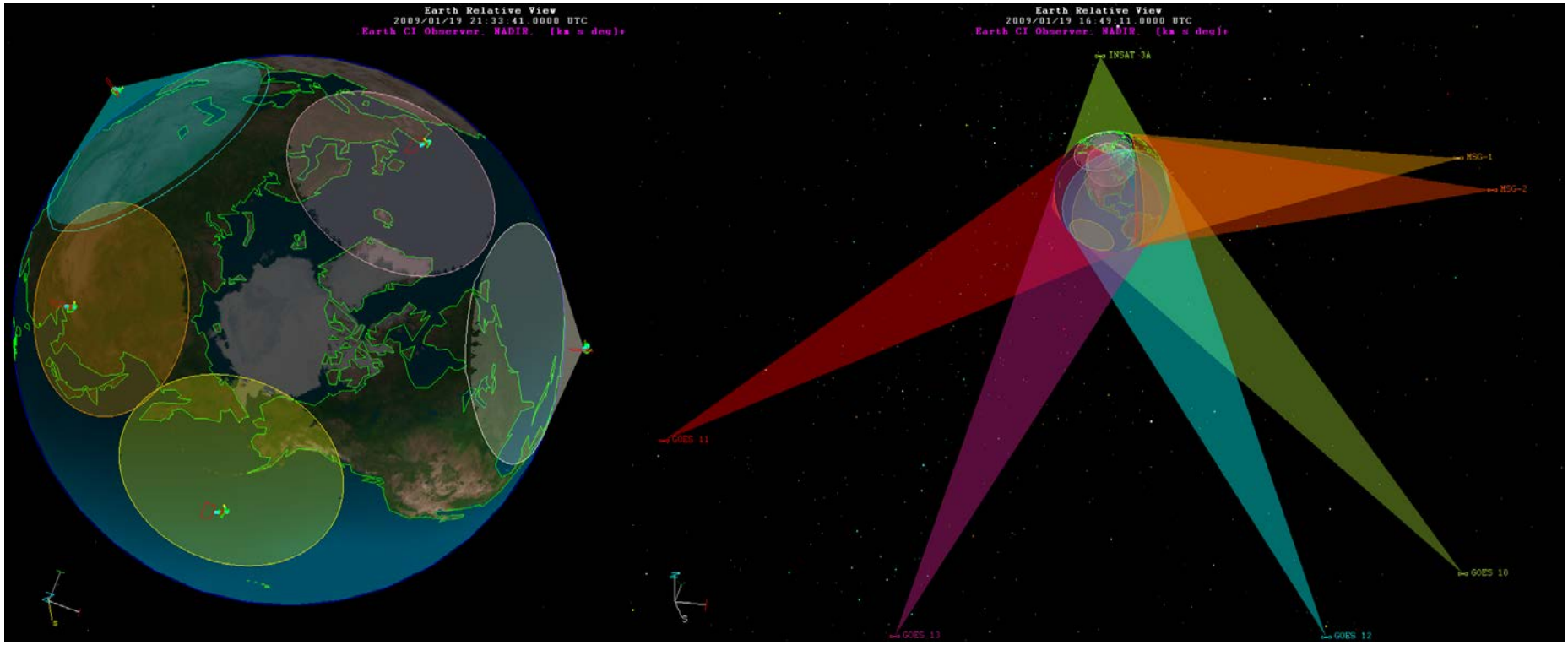
- Near real-time detection of the 406 MHz transmission from an emergency beacon. Even if there is no LEO satellite in view to achieve Doppler for location, GEO satellites work to save lives in 4 ways:
  - Use of Registration Database to contact owner or emergency POC; this allows rescue forces to get more detailed information such as nature of emergency, severity of injuries, number of people involved, etc. and can help determine if alert is actual distress
  - GEOSAR satellites have continuous monitoring of over 1/3 the Earth's surface.
  - GEOSAR satellites have a 46-minute mean time "advantage" for first detection.

Satellites Types

Two types of operational satellites:

Low-Earth orbiting (LEO) satellites orbiting at ~ 850 km

Geosynchronous Earth orbiting (GEO) satellites orbiting at ~ 35786 km

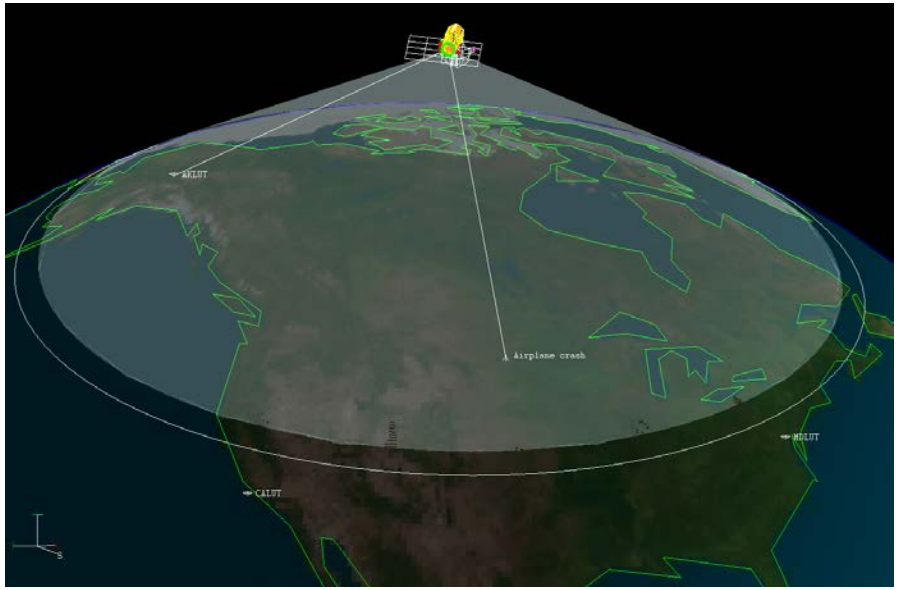


LEOSAR Satellites

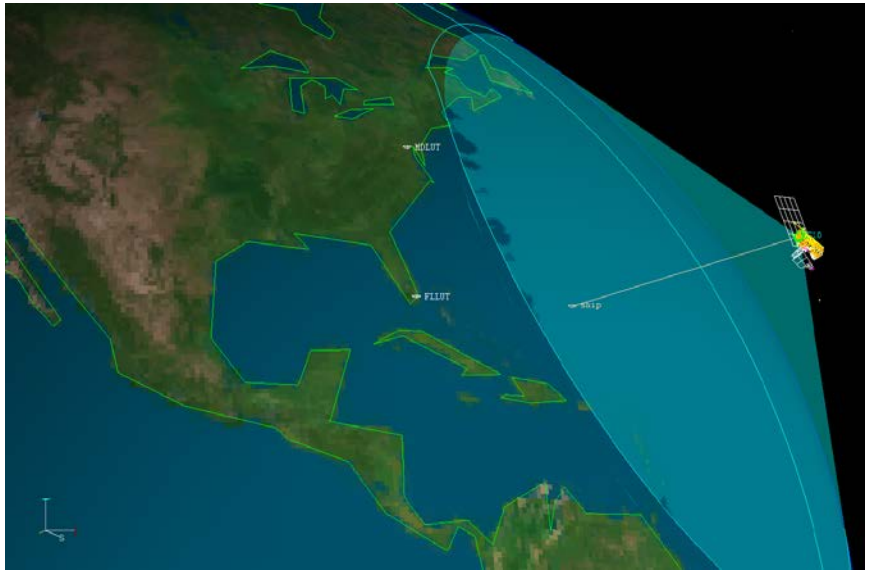
SARSAT

LEOSAR Payloads and concepts

- **Search and Rescue Repeater (SARR)**
  - **Receives 406-406.1 MHz frequency band, then re-transmits band centered at 1544.5 MHz (RHCP).**
  - **No on-board position processing is performed.**
  - **To compute a position, a LEOLUT must be “mutually visible”**

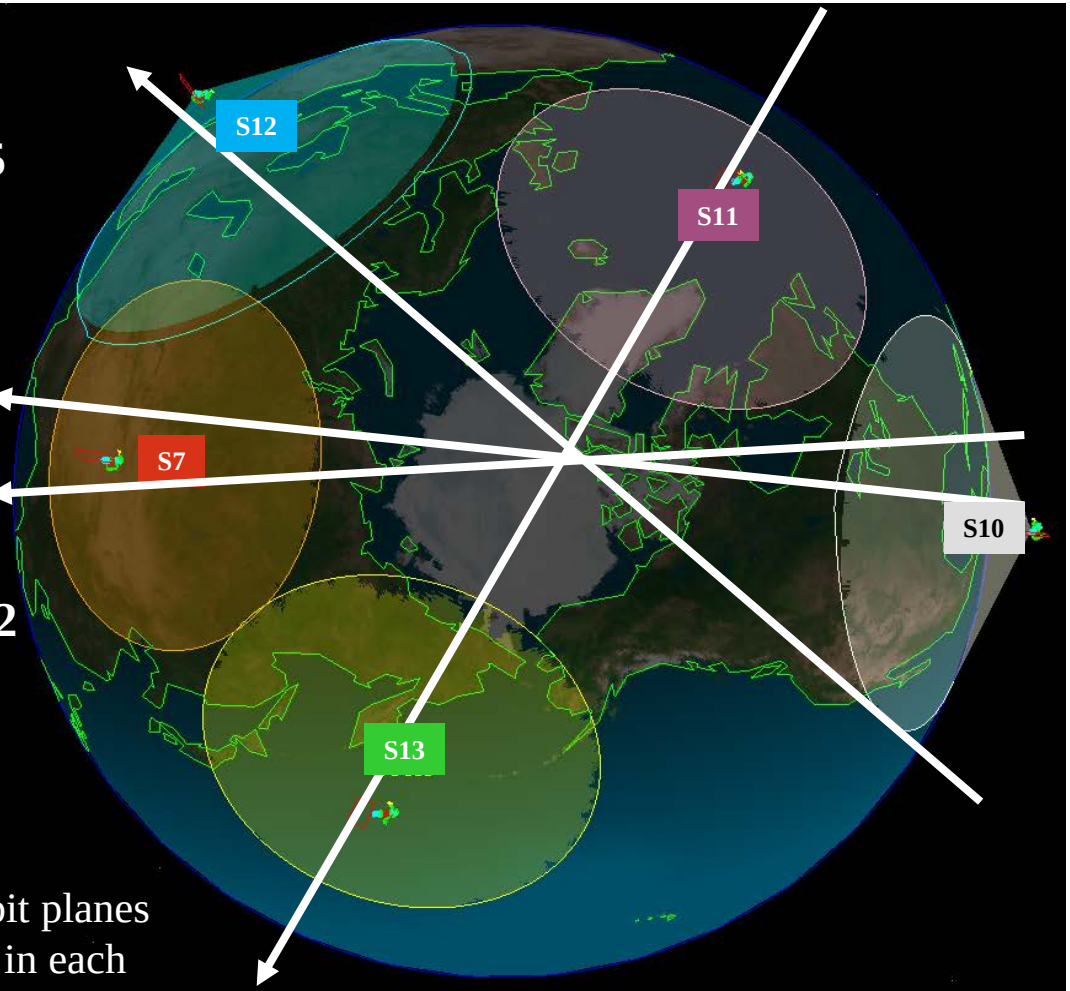


- **Search and Rescue Processor (SARP)**
  - **Digitally extracts the beacon ID, Measures the signal’s carrier frequency and time tags the measurement**
  - **Immediately puts the received 406 MHz beacon uplink message into the continuous 2.4 kbps memory data stream downlink transmission (separate from the SARR Tx signal) and memory contents are completely transmitted on a continual basis (about every 3 minutes)**
  - **Once SARP memory is completely filled, oldest data is purged as new is received**



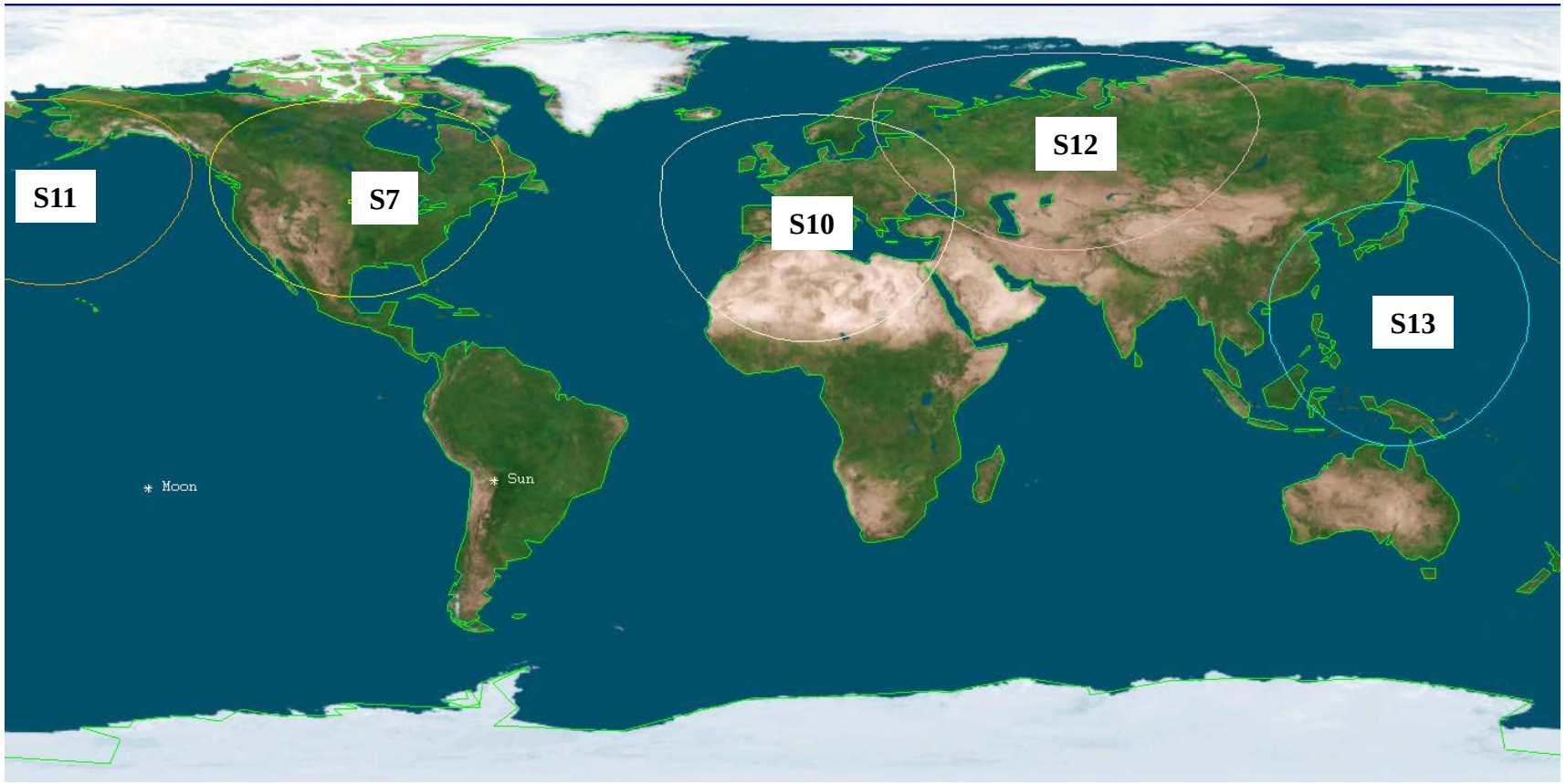
LEOSAR Satellites

- Polar orbiting and 101-105 min. per orbit
- Orbit is 850 km in altitude
- Earth rotates 25 degrees longitude per orbit
- Provides global coverage twice per day
- Presently, 6 operational (S7, S8, S9, S10, S11 & S12

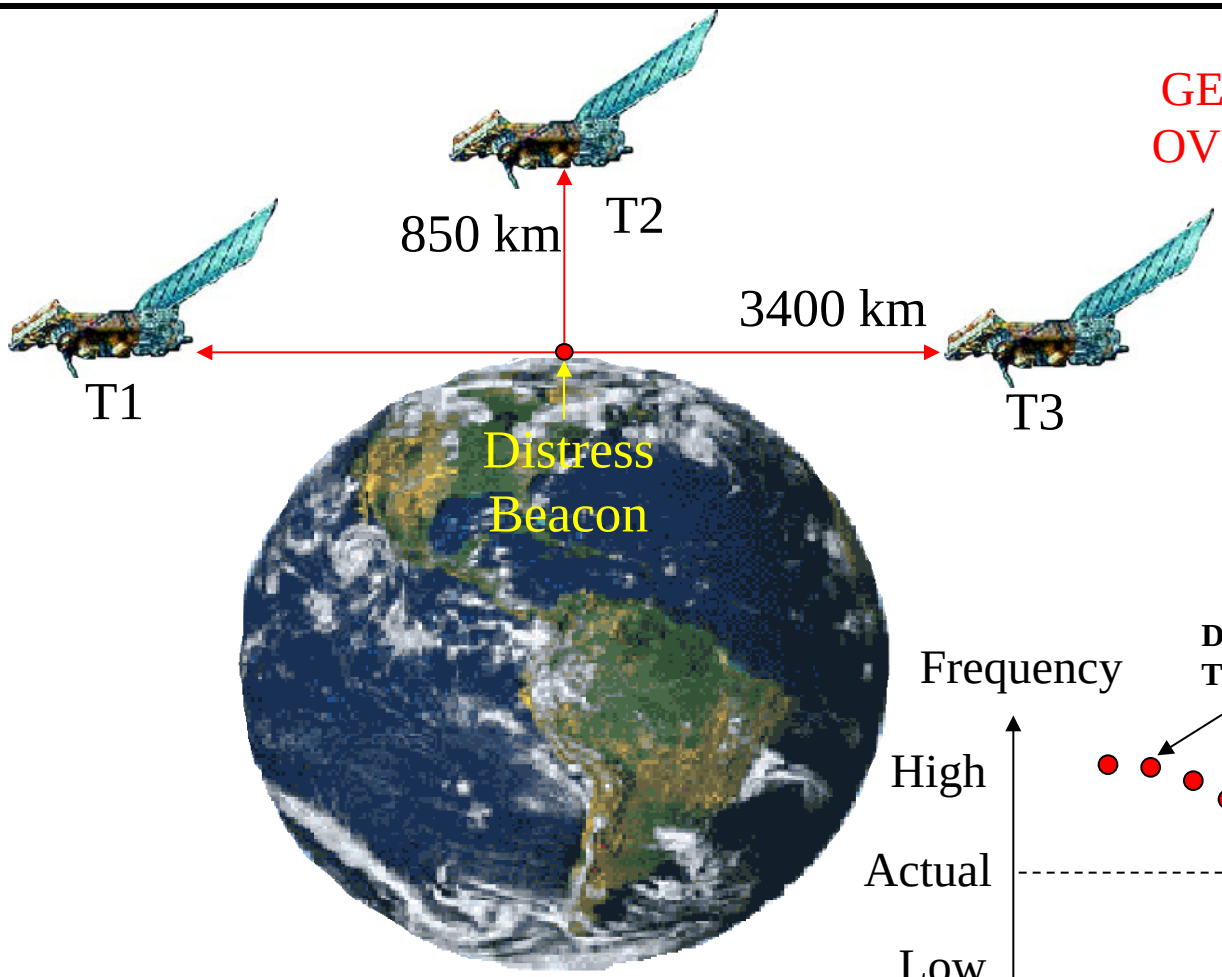


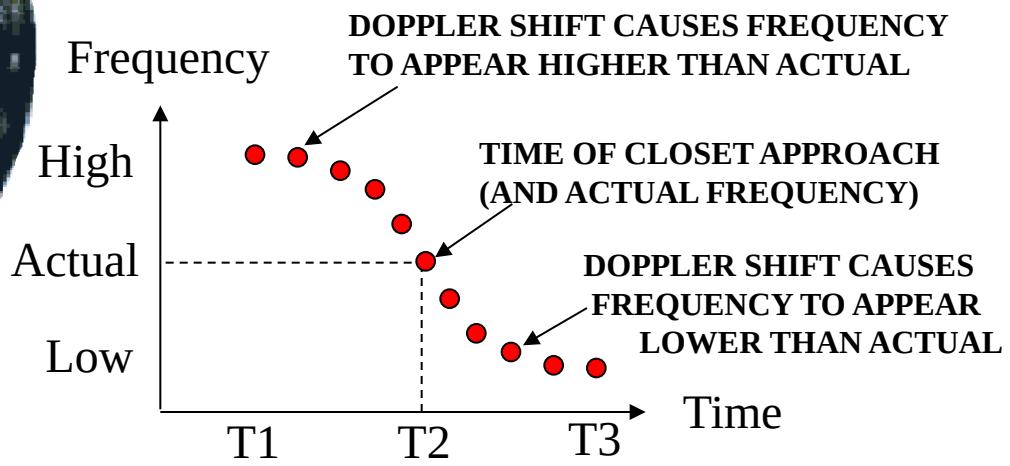
3 ~ distinct orbit planes w 2 satellites in each plane

LEOSAR Instantaneous Coverage



Determining Beacon Locations From LEO Doppler Data





Resolving Ambiguity

Two Pass Solution for a Beacon Located in Brazil

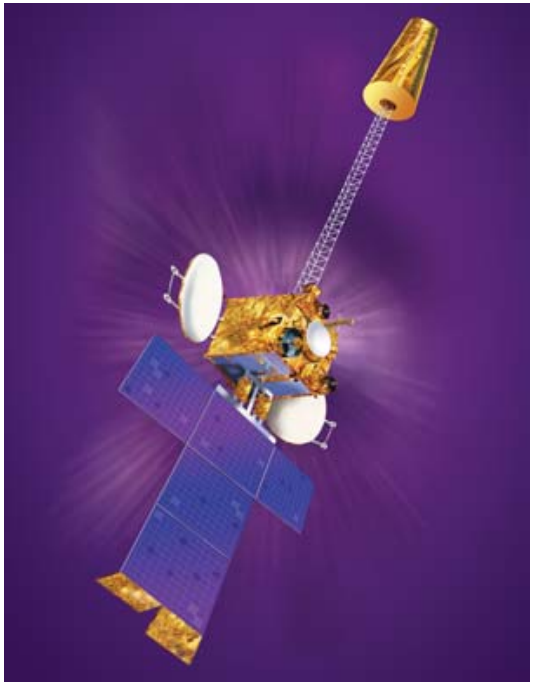
LEGEND: 1 2 ground tracks of successive spacecraft orbits

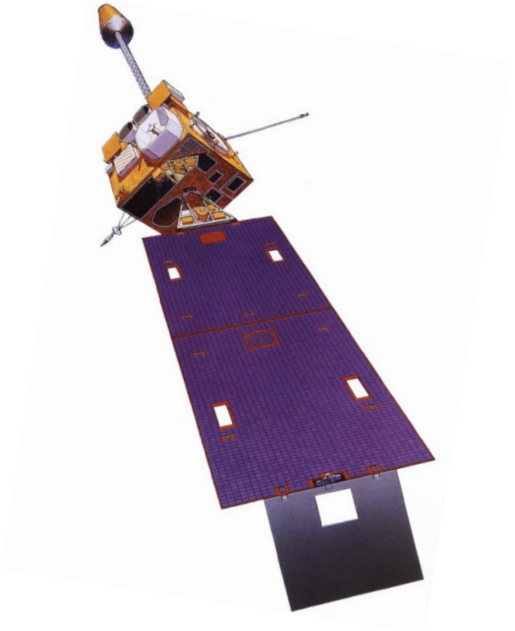
1A, 1B Real and Image solutions from pass 1

2A, 2B Real and Image solutions from pass 2

GEOSAR Satellites

Indian National Satellite (INSAT)



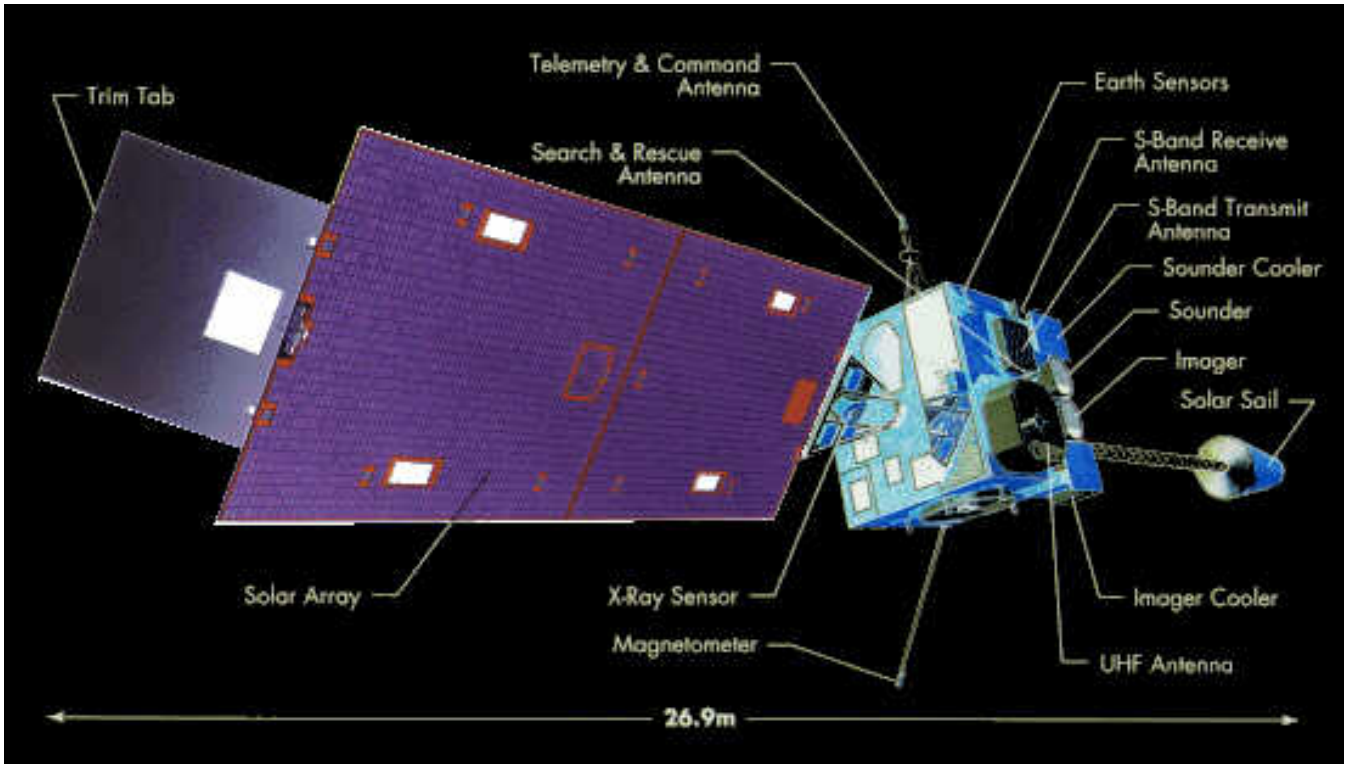


Geosynchronous Operational and Environmental Satellite (GOES)

Meteosat Third Generation (MTG)

NOAA GEO Satellite

Geostationary Orbiting Environmental Satellite (GOES)



UHF Antenna receives 406-406.1 MHz signals and GOES Search and Rescue Repeater (SARR) retransmits band down via S&R antenna centered at 1544.5 MHz (LHCP)

Advantages of LEOSAR System over the GEOSAR System

- **LEOSAR independently computes beacon locations using Doppler shift processing. GEOSAR system does not have Doppler capability, i.e., locates 406 MHz beacons whereas GEOSAR system only detects.**
- **LEOSAR provides a global coverage "over time" for 406 MHz. GEOSAR system does not cover the polar areas, >70 degrees.**
- **LEOSAR provides improved detection probability for obstructed beacons, e.g., ship housings, waves, etc.**
- **LEOSAR has higher link margin, which increases the probability for low power beacon detection.**

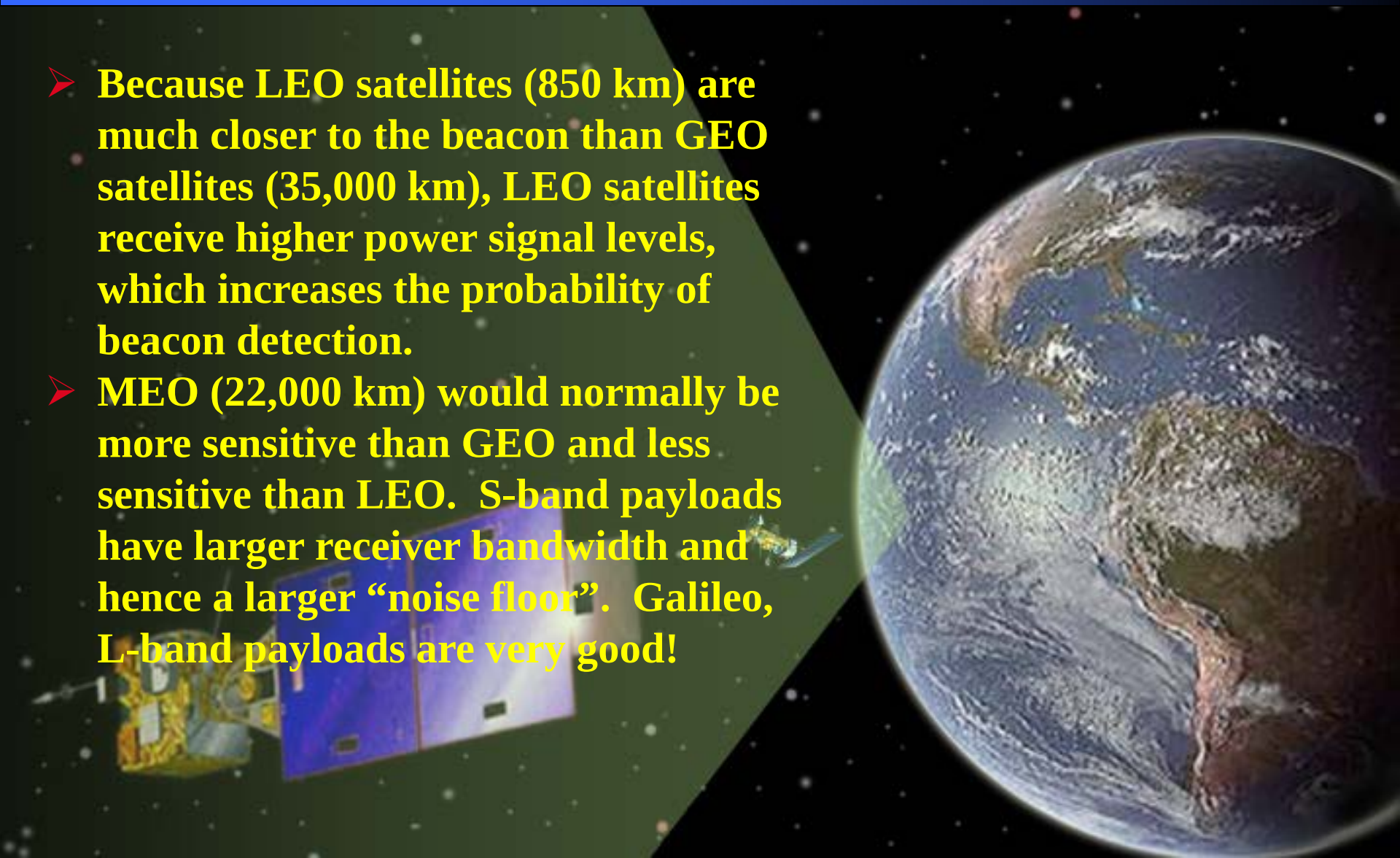
Advantages of GEOSAR System over the LEOSAR System

For 406 MHz beacons only:

- **Near instantaneous detection.**
- **Near instantaneous location determination for beacons with Global Navigation Satellite System capacity (GPS, Galileo)**
- **Continuously monitoring of ~1/3 of Earth's surface**
- **Has a 46 minute mean time 'advantage' for first detection**

Beacon Power Levels with Distance

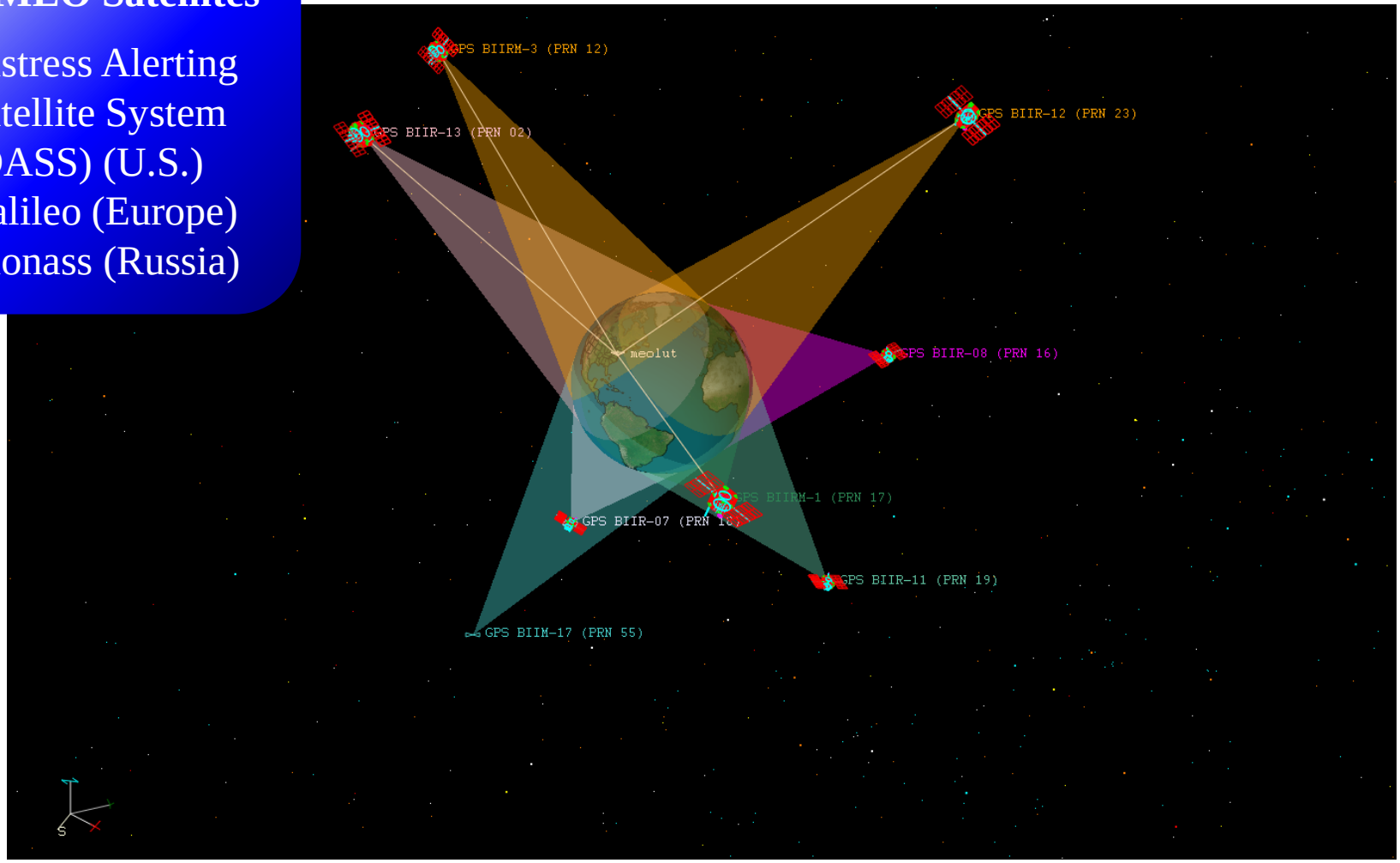
- Because LEO satellites (850 km) are much closer to the beacon than GEO satellites (35,000 km), LEO satellites receive higher power signal levels, which increases the probability of beacon detection.
- MEO (22,000 km) would normally be more sensitive than GEO and less sensitive than LEO. S-band payloads have larger receiver bandwidth and hence a larger “noise floor”. Galileo, L-band payloads are very good!



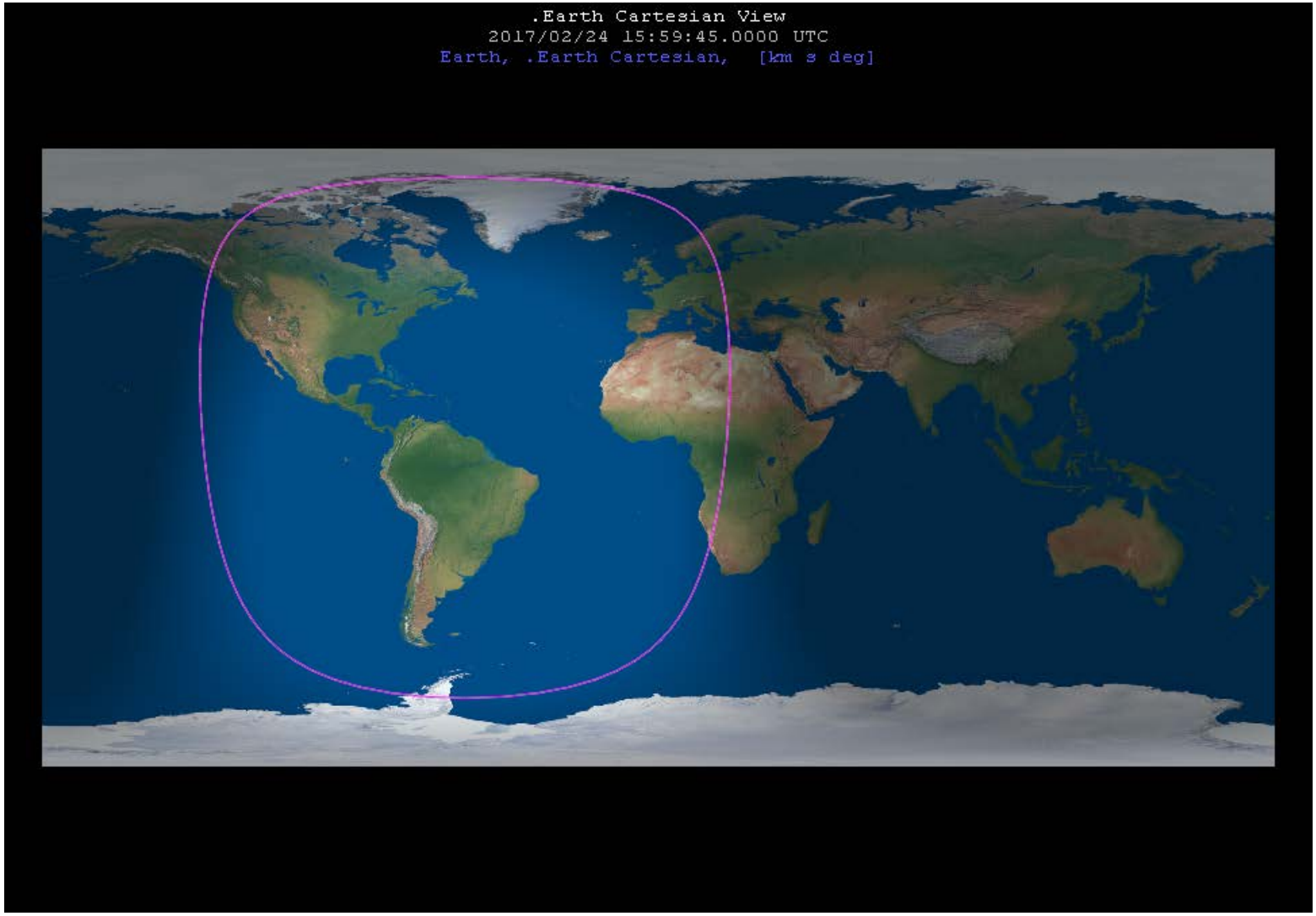
MEOSAR

C/S MEO Satellites

- Distress Alerting Satellite System (DASS) (U.S.)
- Galileo (Europe)
- Glonass (Russia)

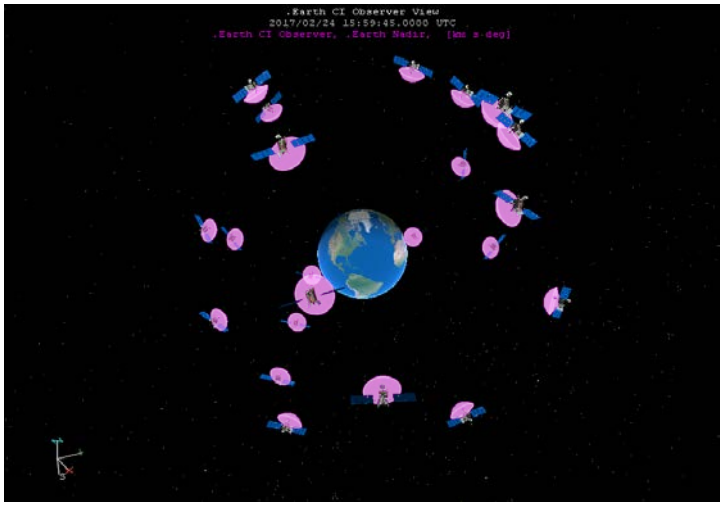


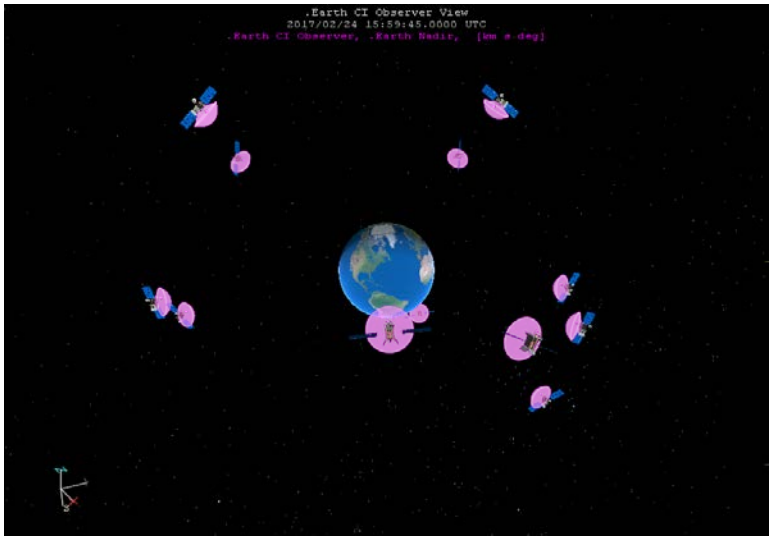
Single MEOSAR footprint



Number of MEOSAR satellites

Currently there are 22 GPS w an Experimental DASS payload S-band downlink (20 functional)

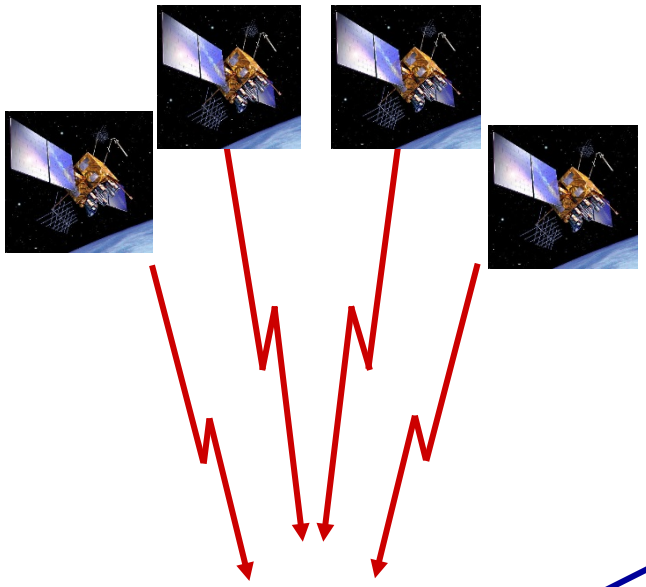




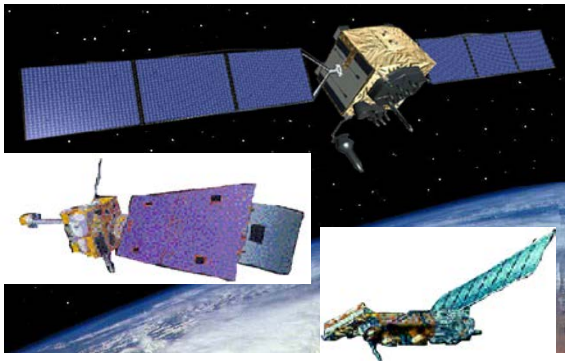
Currently there are 12 Galileo w an L-band SARR payload (10 functional)

Use of GPS in Location Protocol Beacons

4 GPS Satellites



406 MHz Message with Embedded GPS location

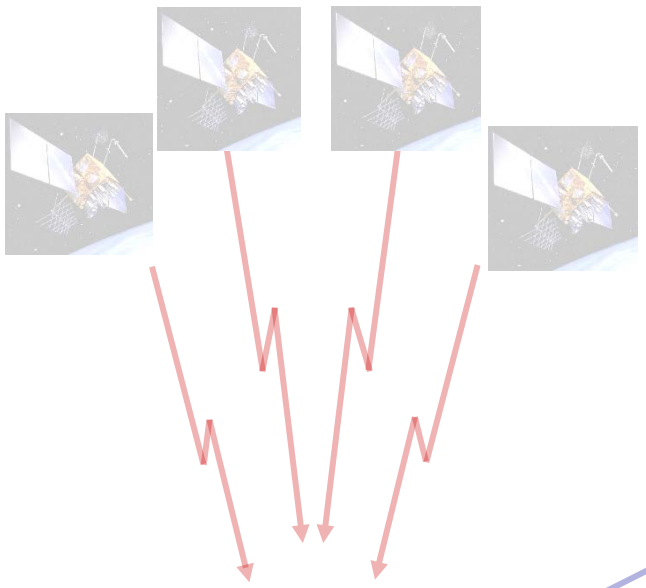


Any C/S Satellites

LUT

>15% of beacons are Location Protocol

Use of GPS in Location Protocol Beacons



GPS Satellites

- 24-satellite constellation
- 4 satellites in view at all times
- Transmit time and orbital data

406 MHz Message with Embedded GPS location

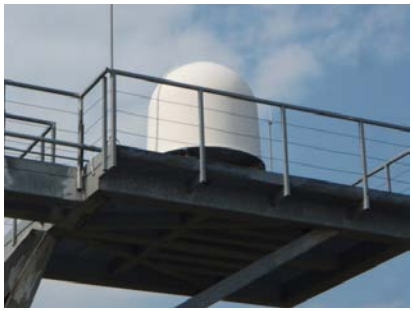
406 MHz Beacon with GPS Receiver

- Uses satellite-beacon time difference to calculate distance from each GPS satellite
- Uses GPS satellite orbital data and distance from beacon to calculate beacon location.
- Encodes location in 406 MHz message. Update time varies by beacon mfgr

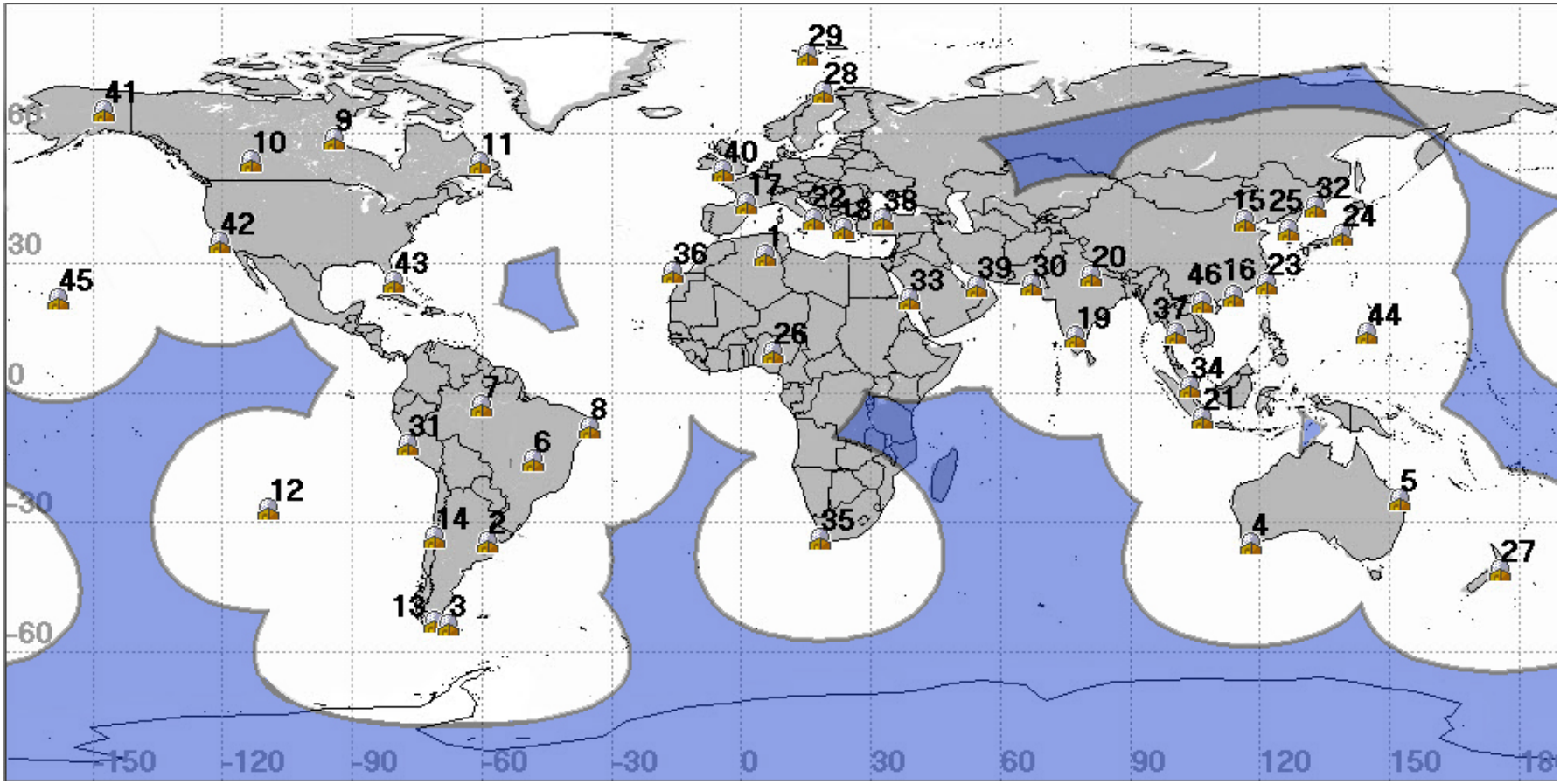
LUT

Ground Segment
LEOSAR Local User Terminals (LEOLUTs)

- Receive and process data from Low Earth Orbit (LEO) satellite search and rescue processors (SARP) and search and rescue repeaters (SARR)
- Combine LEO data with GEO data to improve Doppler processing
- Maintains accuracy by producing a correction of the satellite ephemeris each time a satellite signal is received
- Transmit collected data to the Mission Control Center



Cospas-Sarsat LEOSAR Local User Terminal Locations



Transmissions of beacons activated in the blue areas are stored when they are received by the satellite and later transmitted to a LEOLUT when the satellite passes near that ground station.

U.S. SARSAT Ground Segment

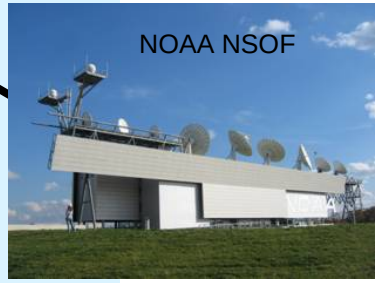
Alaska
NOAA FCDA
2 LEOLUTs

Guam
Andersen AFB
2 LEOLUTs

Hawaii

California
Vandenberg AFB

Maryland*

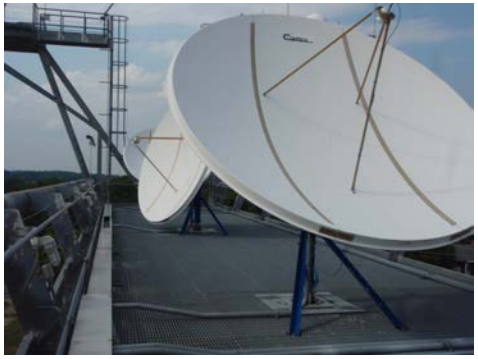


***Maryland has 3 GEOLUTs**
&
1 LEOLUT
US Mission Control
Center

Miami
USCG COMMSTA Miami
2 LEOLUTs
6 antenna MEOLUT

Ground Segment
GEOSAR Local User Terminals (GEOLUTs)

- **Receive and process data from Geostationary Earth Orbit (GEO) satellite search and rescue repeaters (SARR)**
- **Provides beacon location information to MCC when it is included in the digital message of a 406 MHz beacon if the beacon has external or internal navigation device**
- **Transmit collected data to the Mission Control Center**

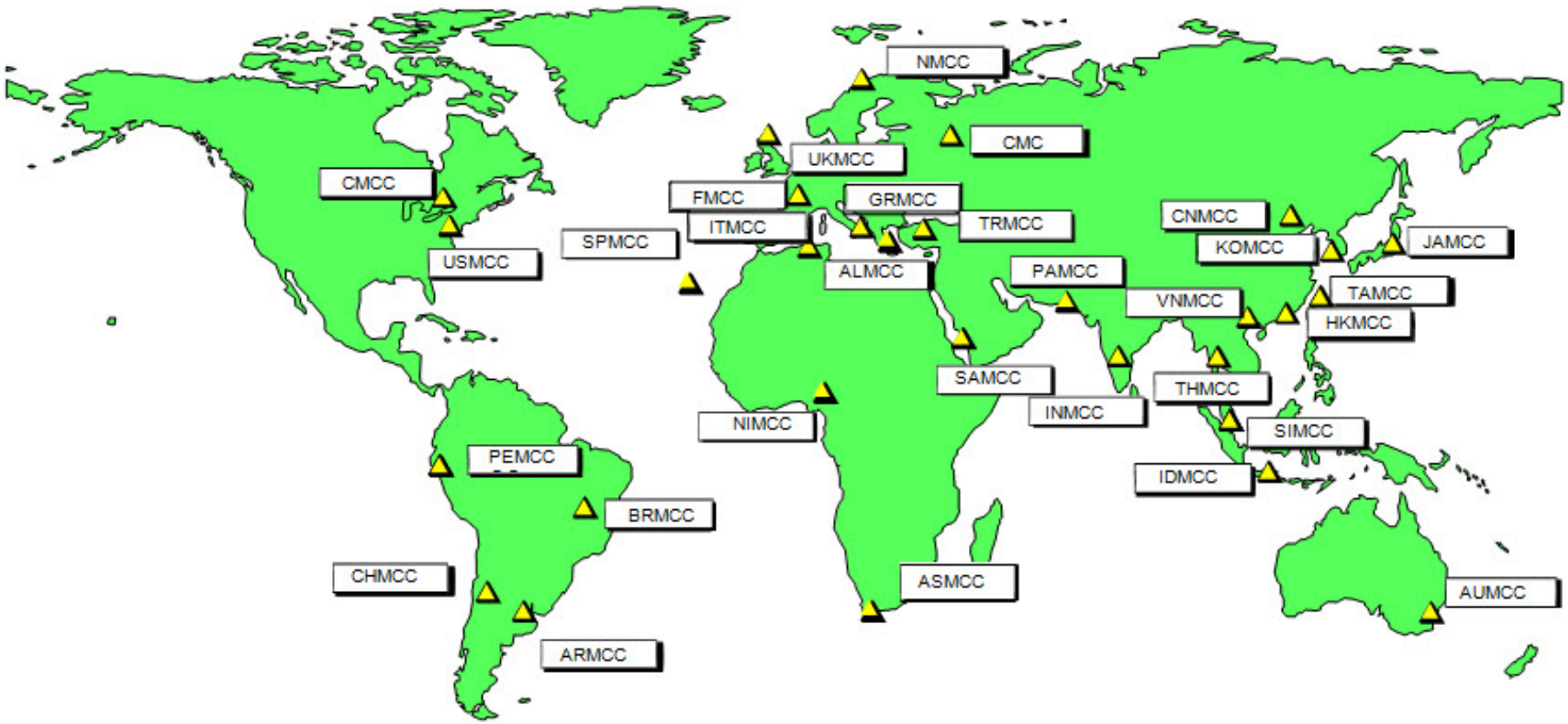


Ground Segment

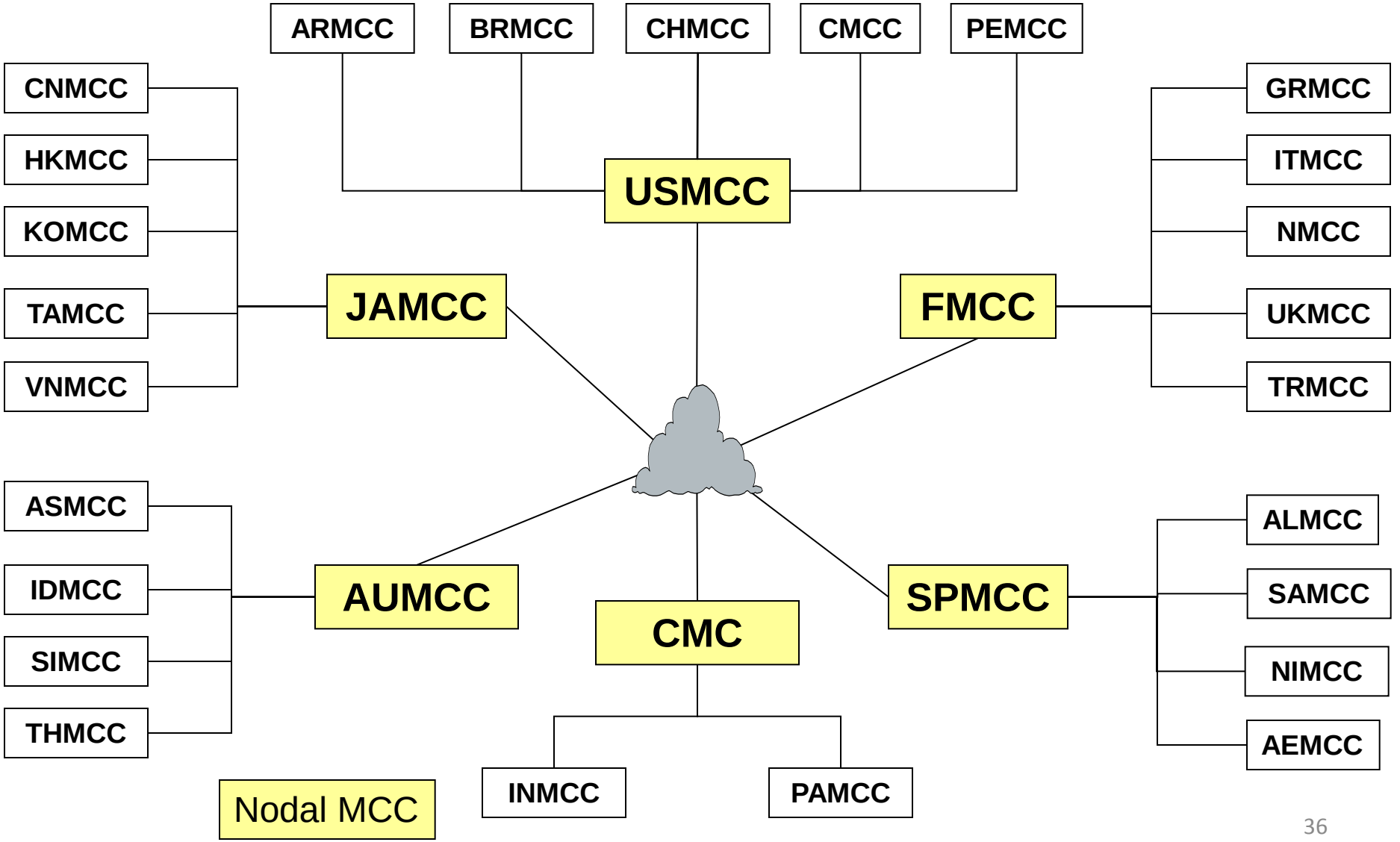
Mission Control Centers (MCCs)

- Receive alerts from national LUTs and foreign MCCs
- Validate, match, and merge alerts to improve location accuracy and determine the correct destination
- Correlate with registration database and append info to alert
- Geographically sort and then transmit alerts to appropriate Rescue Coordination Centers (RCCs) and SAR Points of Contact (SPOC)
- Filter redundant data
- Perform System support and monitoring functions

Cospas-Sarsat Mission Control Centers



MCC to MCC Data Distribution



SARSAT Challenges

- MEOSAR early operations with Distress Alerting Satellite System (DASS)
- USMCC recode
- RGDB recode
- Transition to new satellites (GOES-R and MEOSAR – SAR/GPS, Galileo, GLONASS)
  - Aging LEO Satellites
    - Cooperative Data and Rescue Services (CDARS) – NOAA's next polar satellite planned for Q1 FY2021 (December 2020)

Questions?