Communications Research Centre Canada
An Agency of Industry Canada

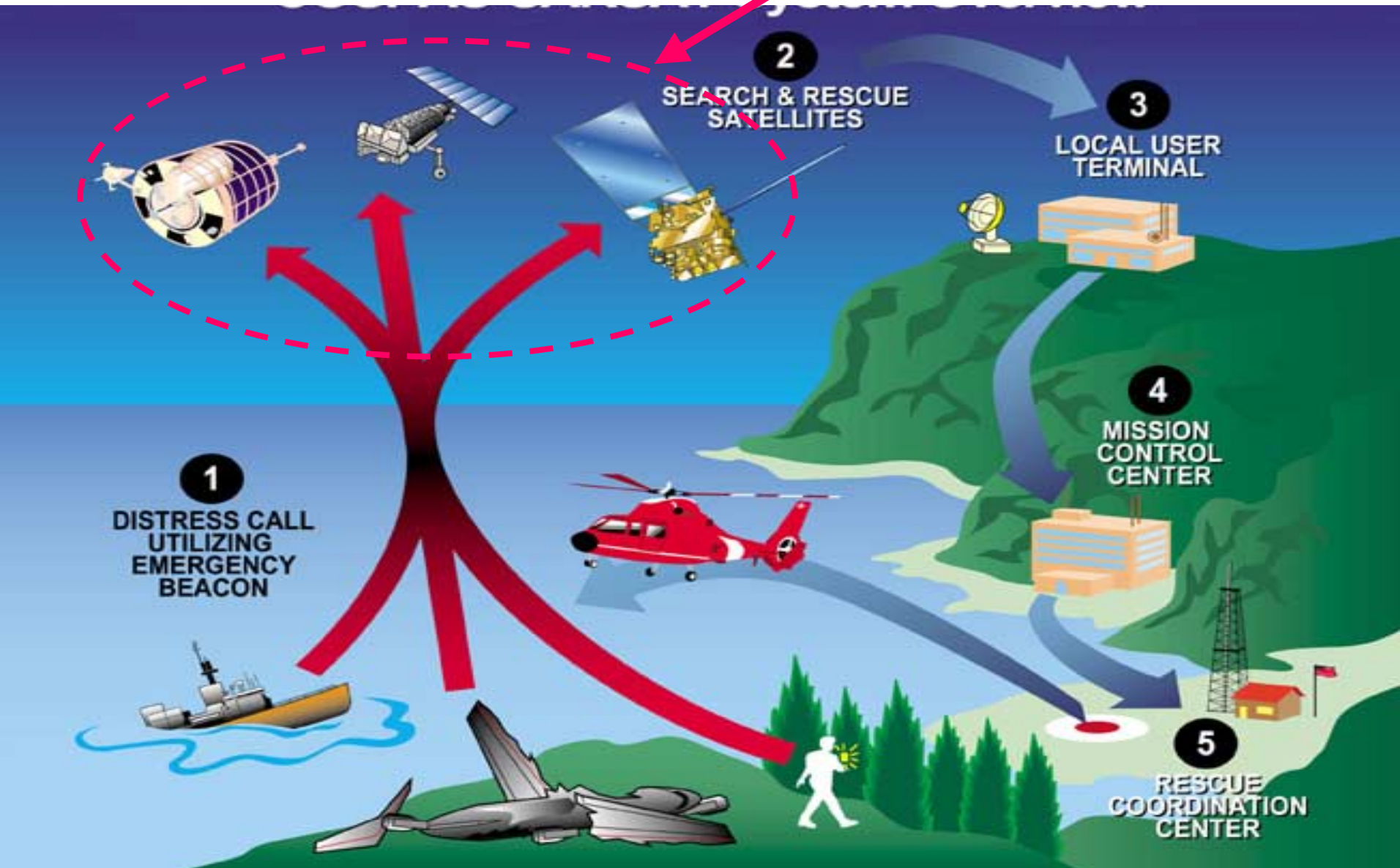
Centre de recherches sur les communications Canada
Un organisme d'Industrie Canada

Description of the Cospas-Sarsat Space Segment

UN/RSA Training Course on
Satellite-Aided Search and Rescue
Cape Town, South Africa

Jim King
CRC Canada
22 Nov 2006

COSPAS-SARSAT Space Segment



Outline

- Background: Canada in Space
- Introduction to satellites, orbits,…
- Cospas-Sarsat LEOSAR, GEOSAR and future MEOSAR Systems
- Benefits of each system
- GNSS and use with C-S

Canada in Space

- Canada was 3rd nation in space- *Alouette* satellite 1962
- Several other satellites since then:
  - Space science
  - Communications satellites
  - Earth Observation (Radarsat)
- **Search and Rescue (Cospas-Sarsat)**

Canada in Space

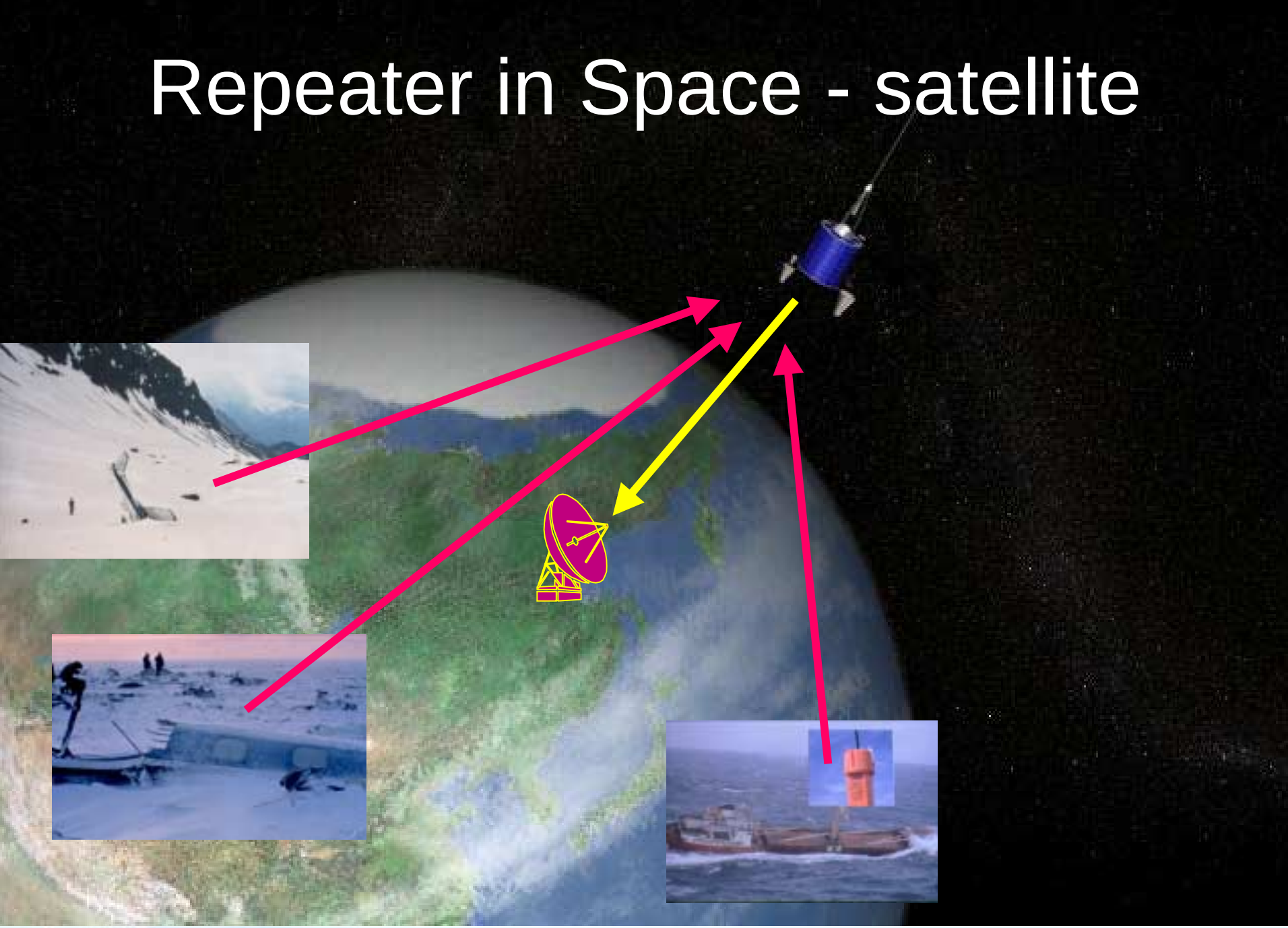
- Robotic arms on space shuttle and station
- Canadian Astronauts
- National SAR Secretariat (NSS)
- Canadian Space Agency (CSA)

Why SARSAT? - It was needed !

- In 1970s planes and ships already carried 121.5 MHz distress beacons
- No communications available in remote areas
- “Space Age” was here

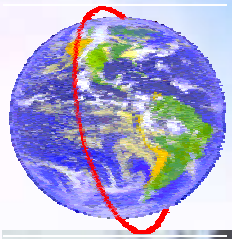
Repeater in Space–800km tall tower

Repeater in Space - satellite



SARSAT:Proof of Concept –1970s

- Sarsat concept studies
- First experiments in 1976 (30 years ago)
- Canada & USA partners in studies
- France & Russia soon joined, then many others
- Industry built world's first operational LEOLUT-1981

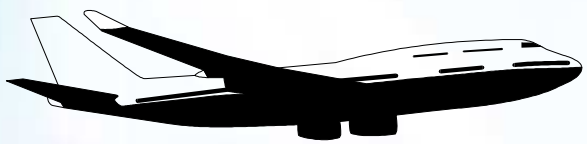


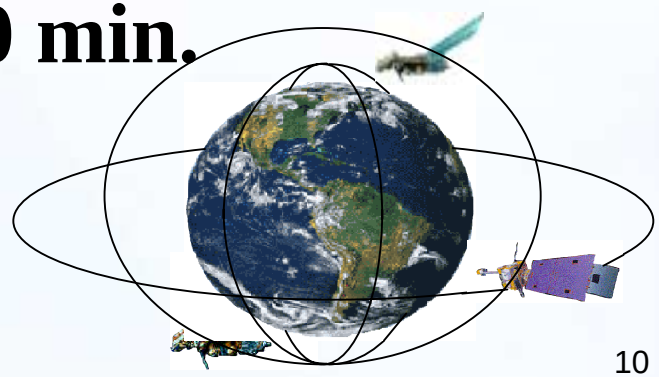
Proof of Concept LEOLUT in 1976

OSCAR-6 Satellite Experiment at CRC in Ottawa - 1976

Satellite Orbits

- Various types of satellite orbits:
  - Low-Earth orbit (LEO - 1 000 km)
  - Medium-Earth orbit (MEO – 20 000 km)
  - Geostationary-Earth orbit (GEO – 36 000 km)
- various inclinations of orbits (90, 55, 0 degrees)
- Lower satellites move faster to stay in orbit
- LEO Sat traverses Africa in 20 min.
- Jumbo Jet takes 10 hr!



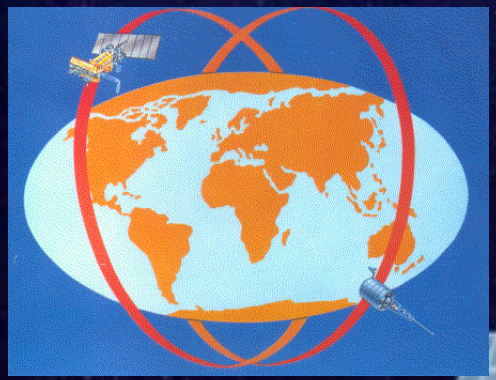


LEOSAR- polar orbit

LEOSAR

- Periodic, global coverage
- Each satellite scans the entire globe twice a day
- Frequent polar coverage
- longer “waiting time” for satellite near equator
- gives Doppler shift

Cospas-Sarsat LEOSAR Satellites

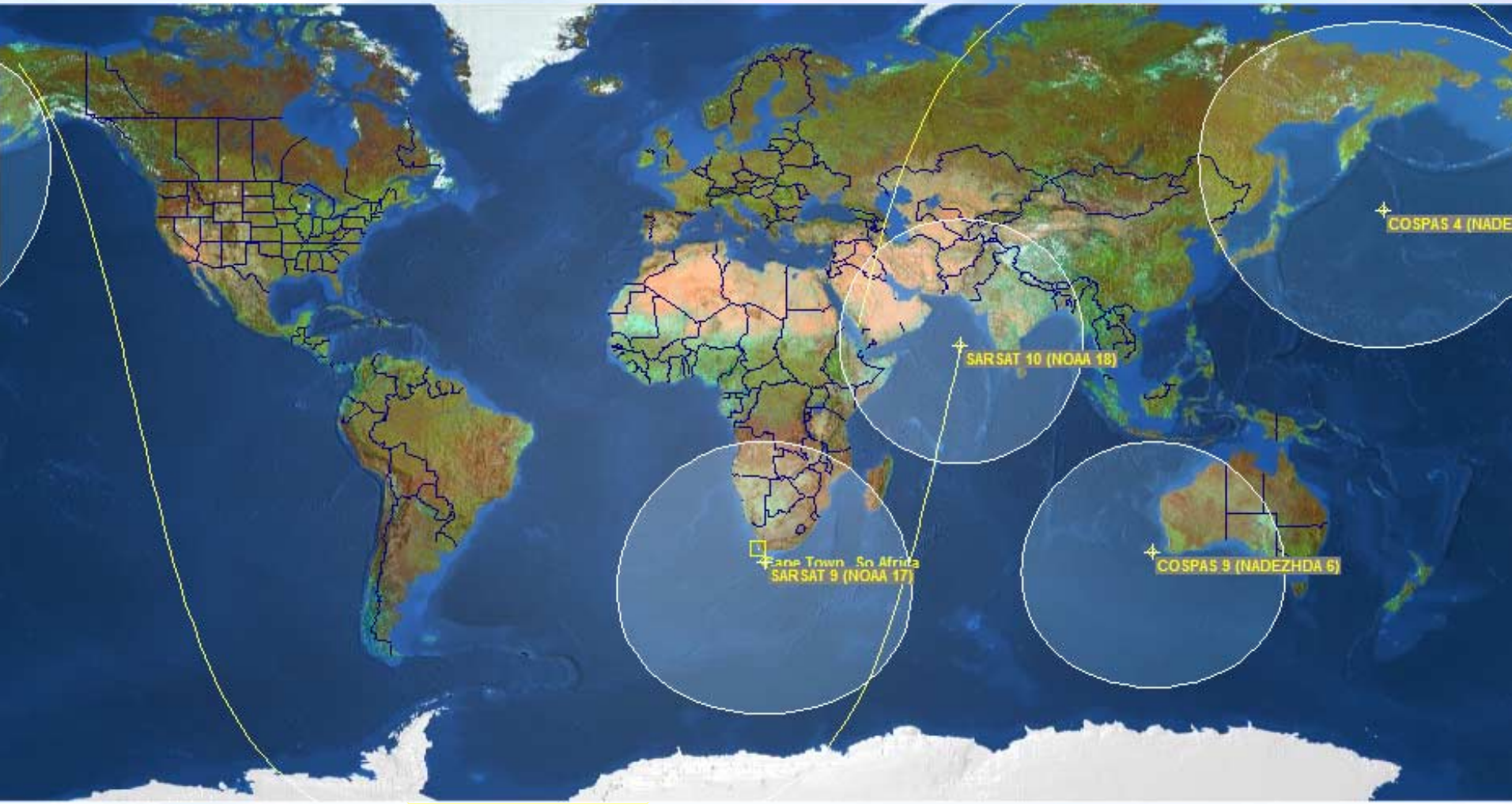


SARSAT

COSPAS

LEOSAR Footprints

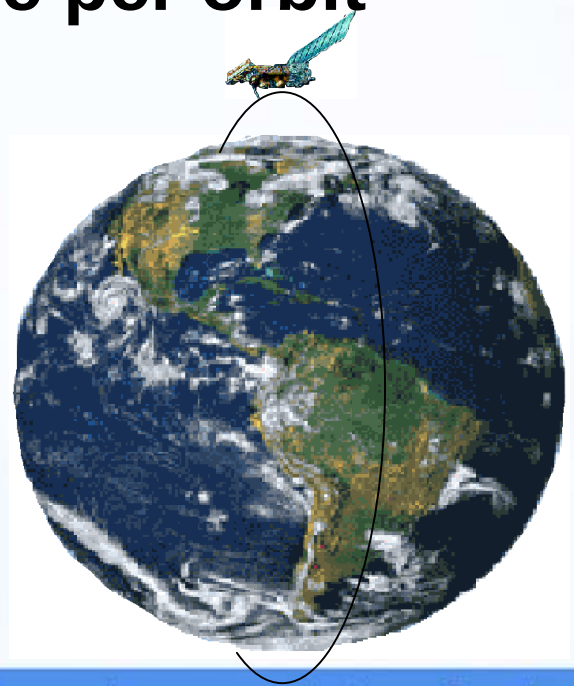
about size of a continent & moves quickly



4 LEOSAR moving footprints

LEOSAR Satellites

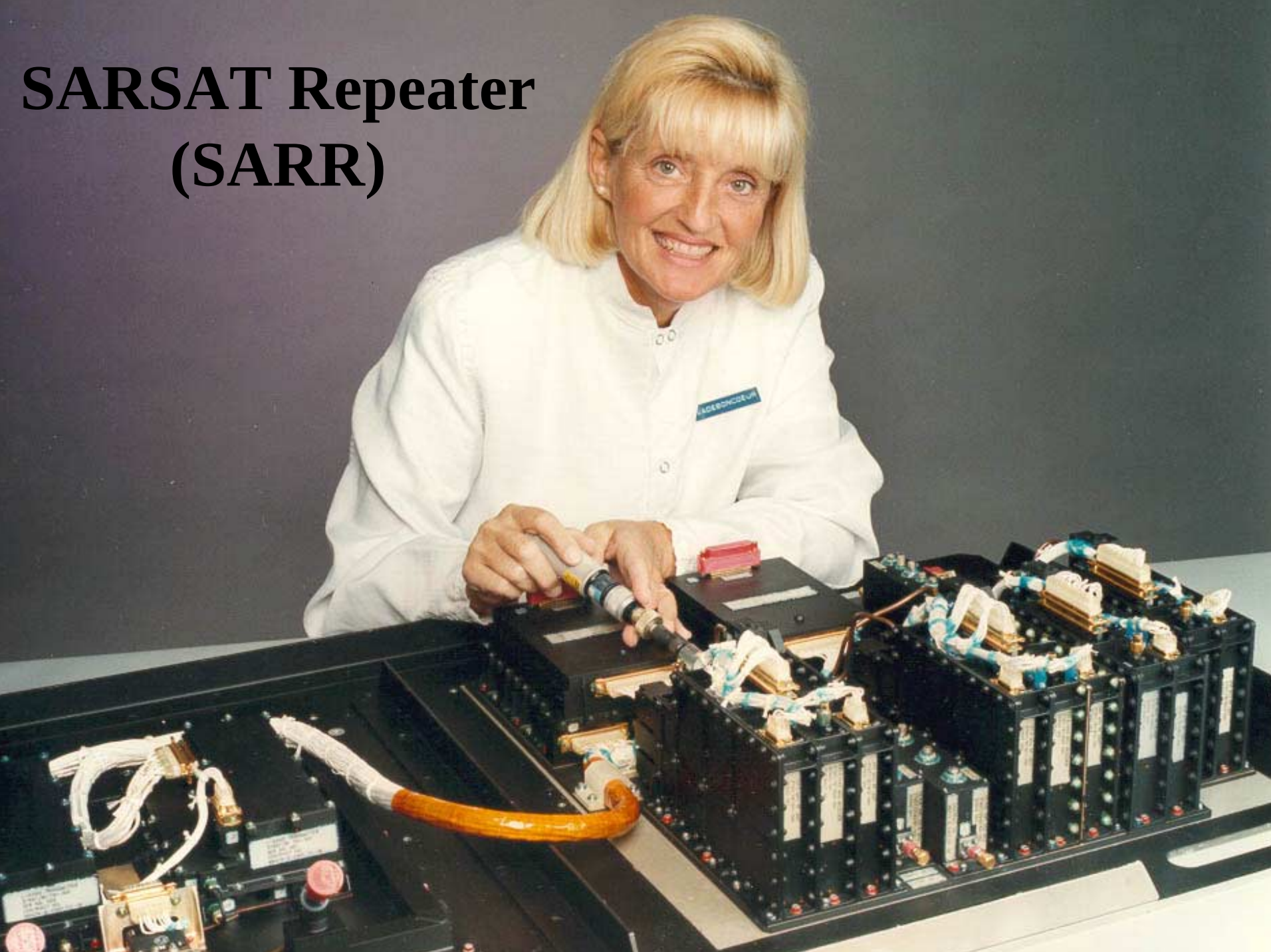
- Polar orbiting and 101-105 minutes per orbit
- Orbit is 850 – 1 000 km in altitude
- Fixed orbital plane and Earth rotates beneath it
- Earth rotates 25 degrees longitude per orbit
- Provides global coverage
- Presently 6 operational
  (S7, S8, S9, S10, C4 & C9)
  (& S11 soon: being tested in orbit)



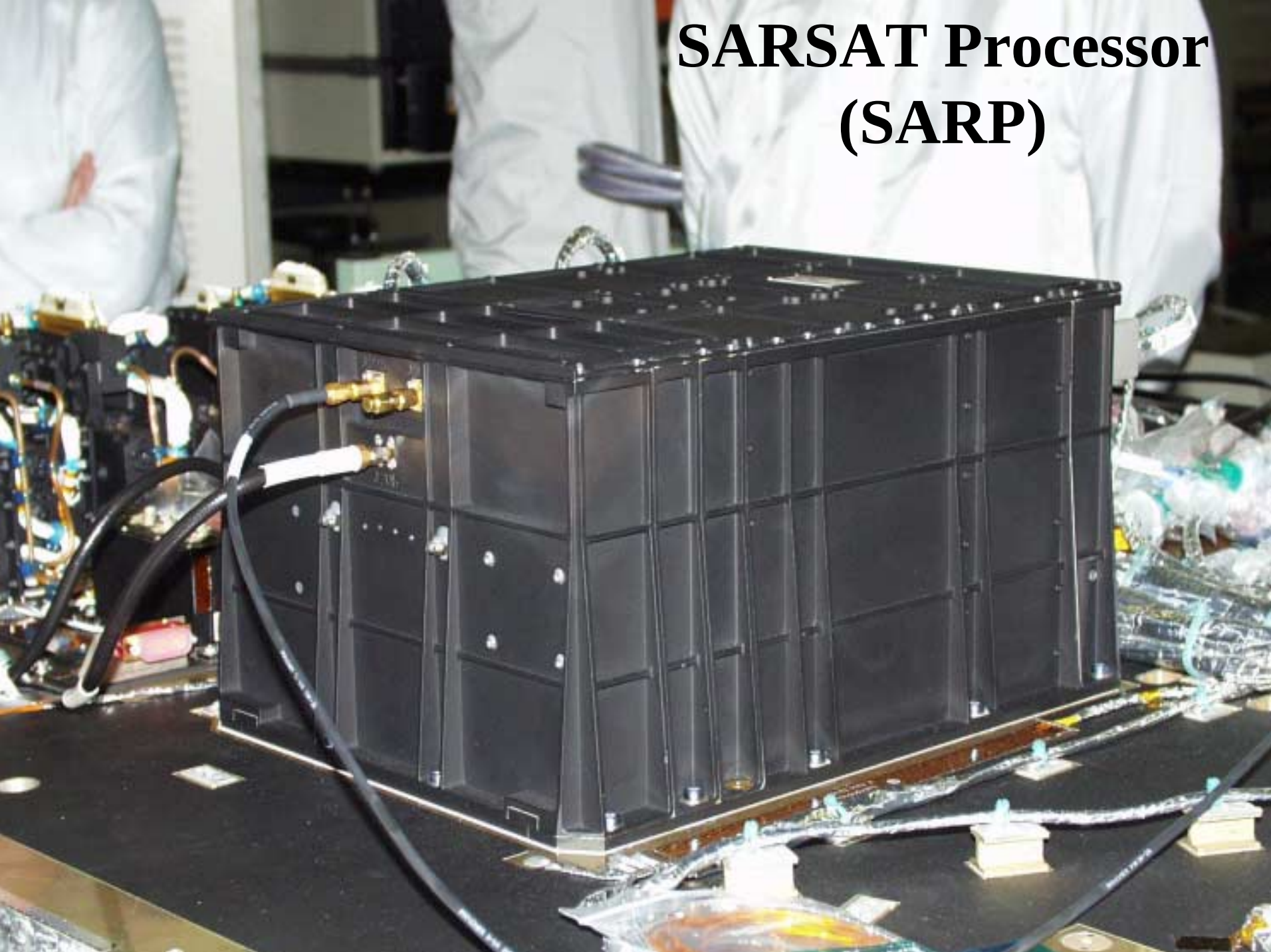
Space Segment Providers and On-Board Instruments

- **LEO Space Segment and Instrument Providers**
  - **SARSAT**
    - **Canada – SAR Repeater**
    - **France – SAR Processor**
    - **U.S. – Antennas, Satellite and Launch**
  - **COSPAS**
    - **Russia –Repeater, Processor, Antennas, Satellite and Launch**

SARSAT Repeater (SARR)

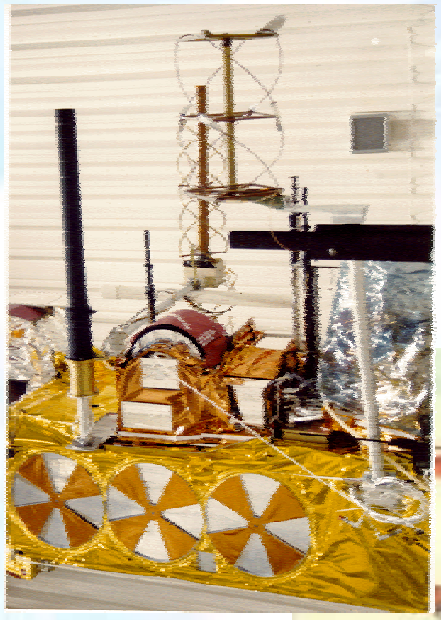


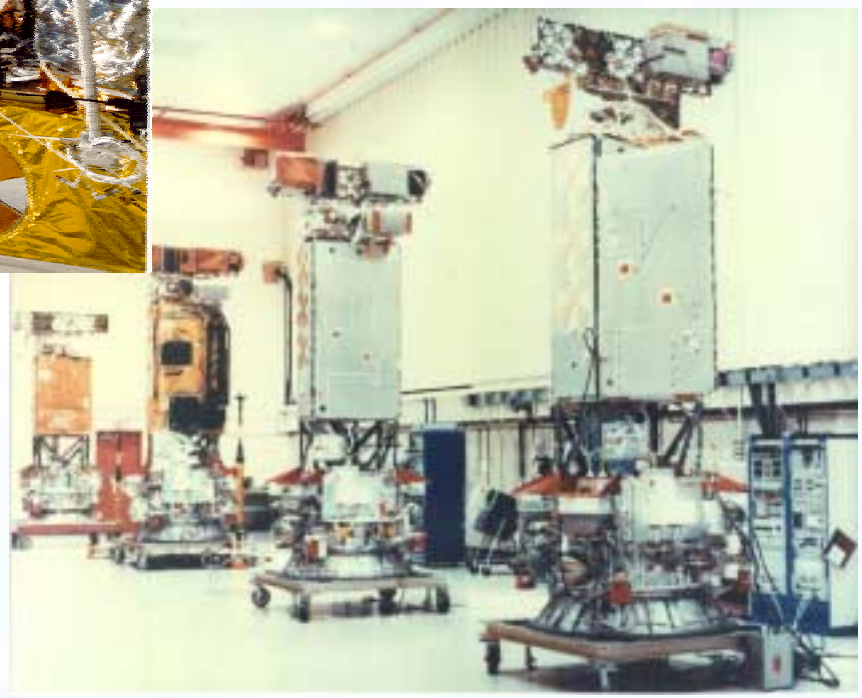
SARSAT Processor (SARP)

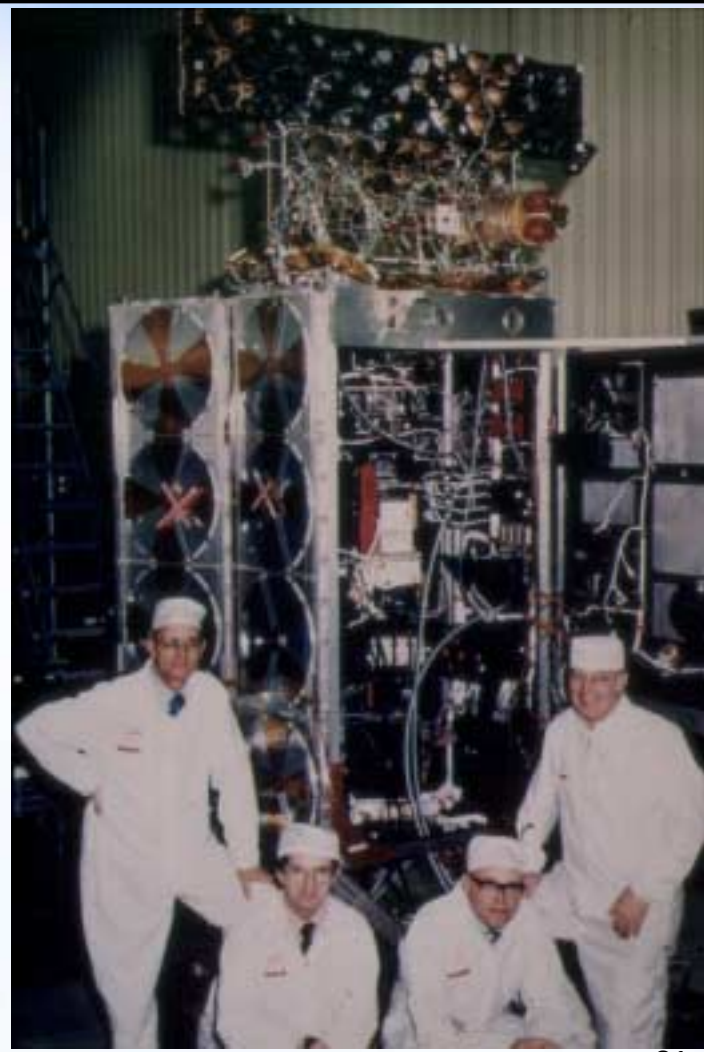


Sarsat SARR & SARP

Sarsat Antennas & NOAA Satellites





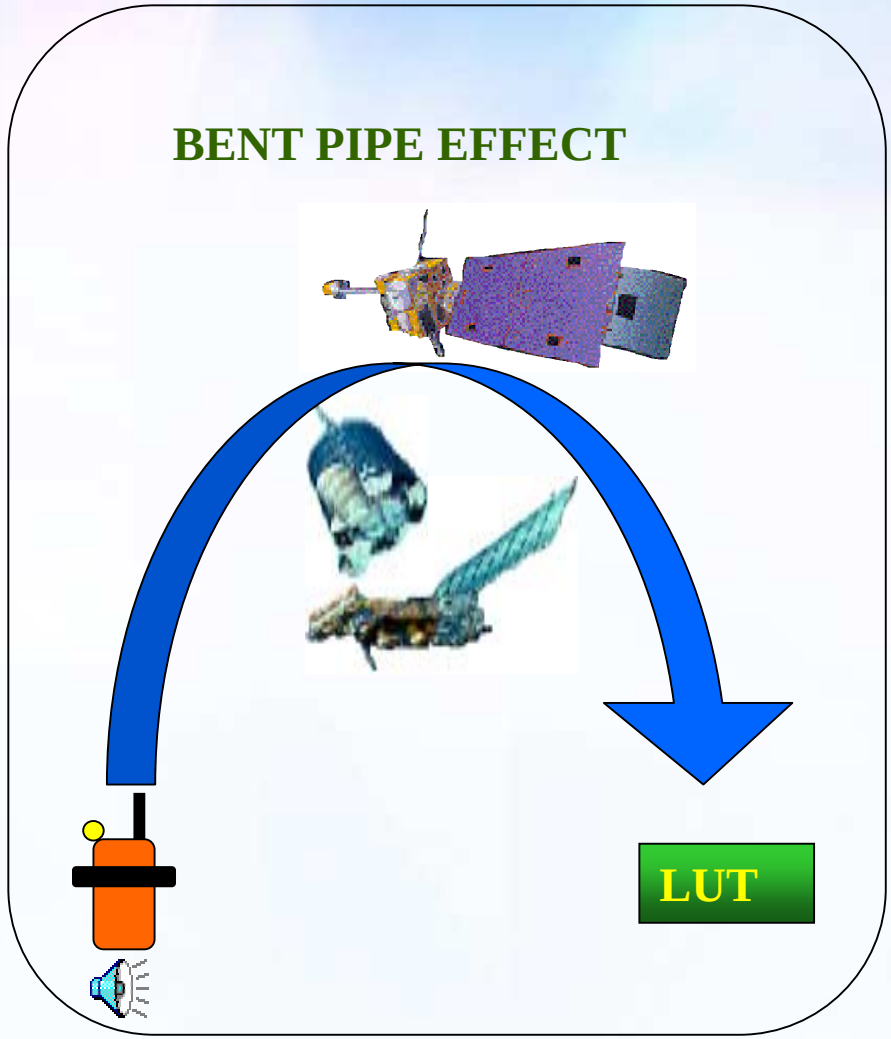


Cospas Satellite (full scale model) & Scientists

Satellite Launches

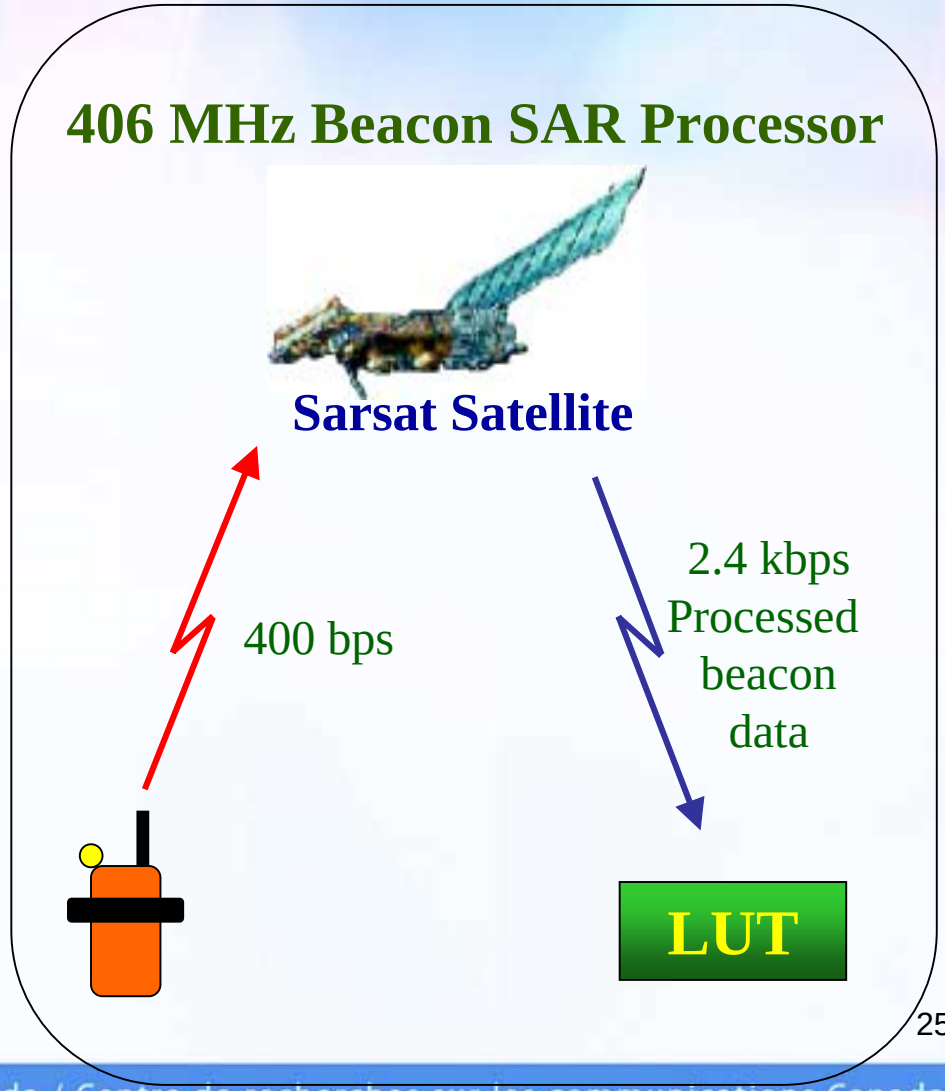
COSPAS-SARSAT Repeater

- **LEOSAR Repeater:**
  - Receives at 121.5, 243, and 406 MHz
  - transmits a multiplexed downlink signal at 1544.5 MHz.
  - No processing is performed
  - Repeater has prime & backup units

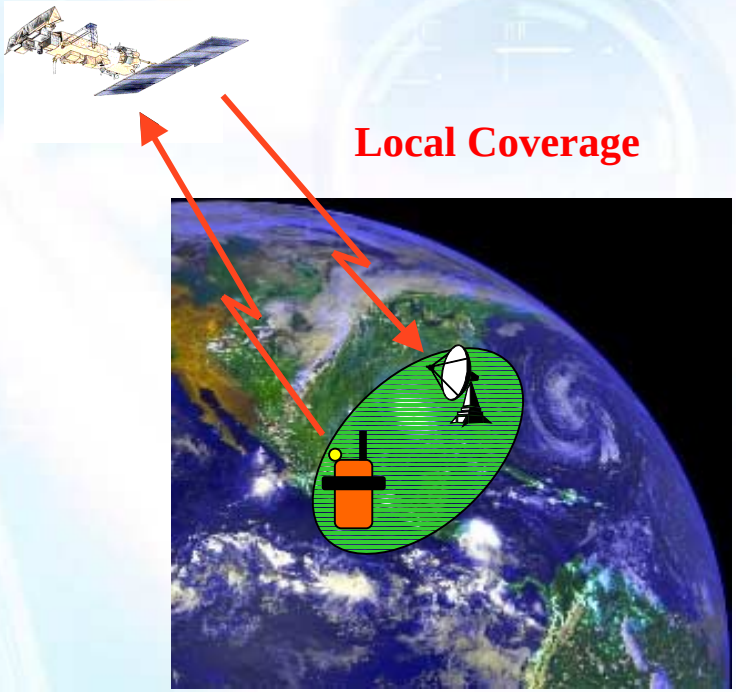


SARSAT Processor and On-Board Memory

- **SAR Processor**
  - Receives beacon signal & ID
  - Measures the frequency
  - Time tags the frequency measurement
  - converts and amplifies the 406 MHz beacon uplink into a 2.4 kbps data stream
- **On-Board Memory**
  - Stores the processed data
  - Continually transmits the stored data
  - Data is purged as new is entered

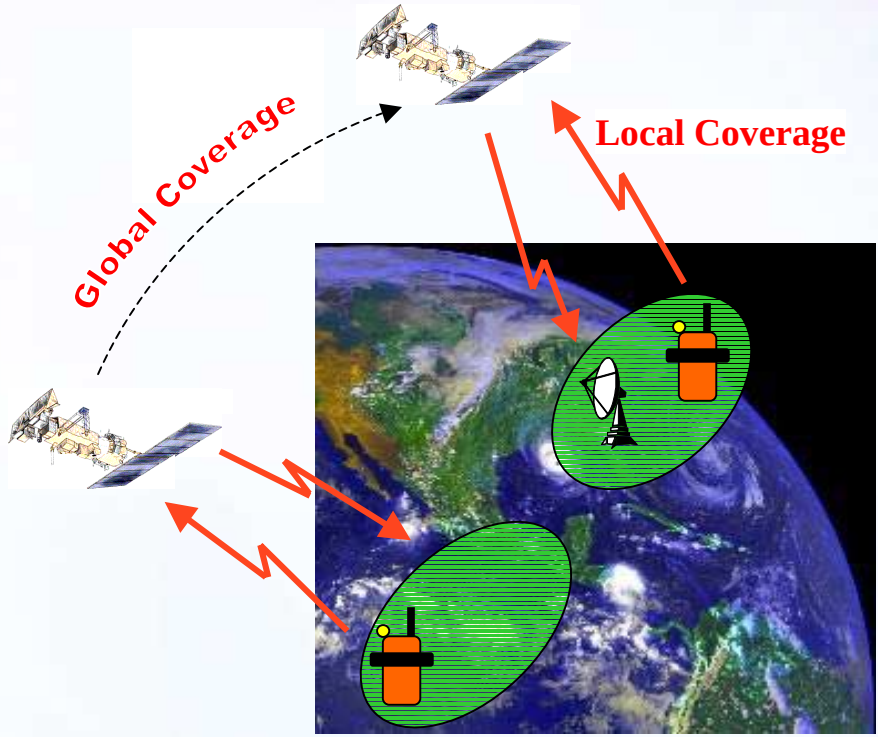


LEO Local and Global Coverage

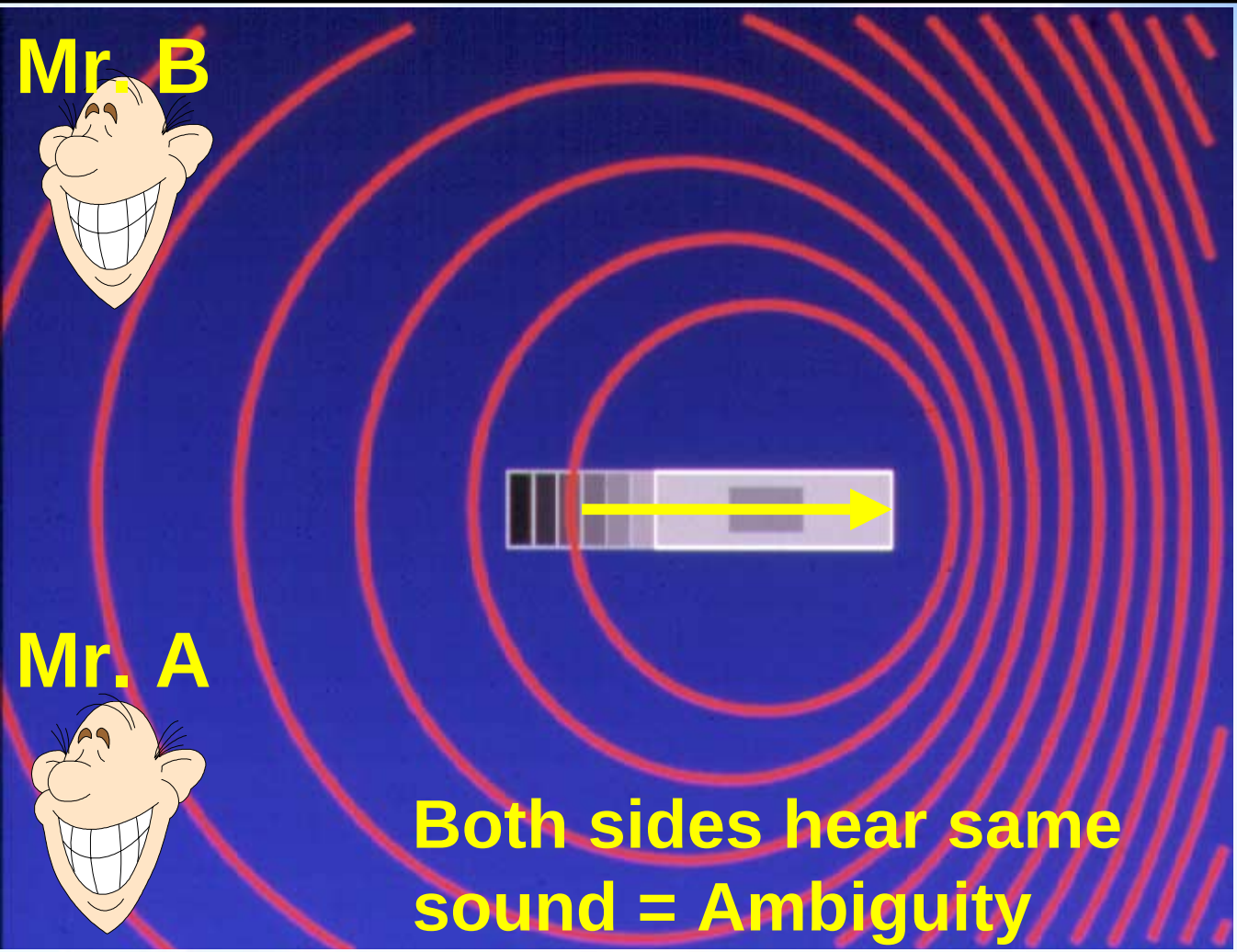


Detection of a 121.5/243 MHz beacon requires mutual visibility between beacon, satellite and ground station (LUT)

406 MHz beacon detections can be stored on board the satellite and re-broadcast later

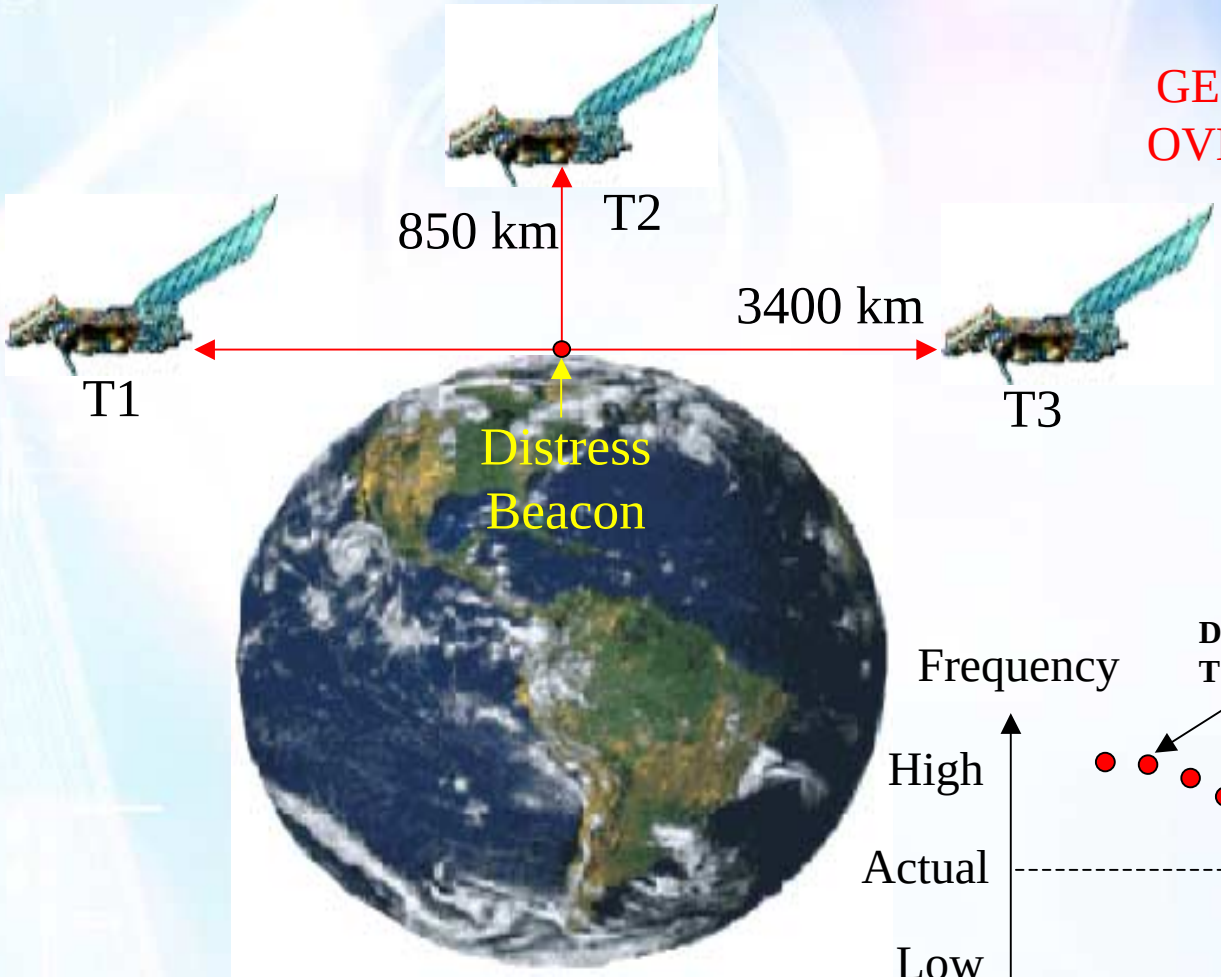


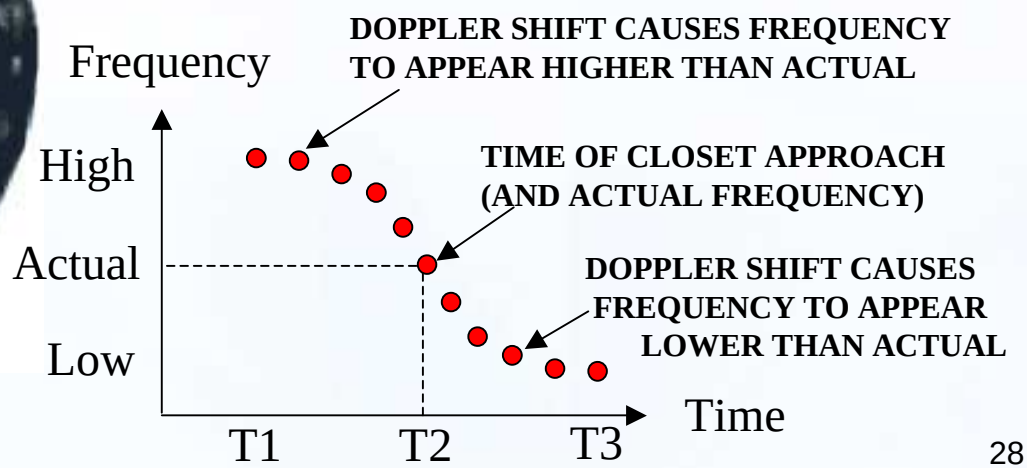
Doppler Effect



- SOUND WAVES AROUND A MOVING CAR
- WAVES "BUNCHED UP" IN FRONT (HIGHER PITCH)
- WAVES "SPREAD OUT" BEHIND (LOWER PITCH"
- OBERVER "HEARS" DIFFERENT NOTES AS CAR PASSES

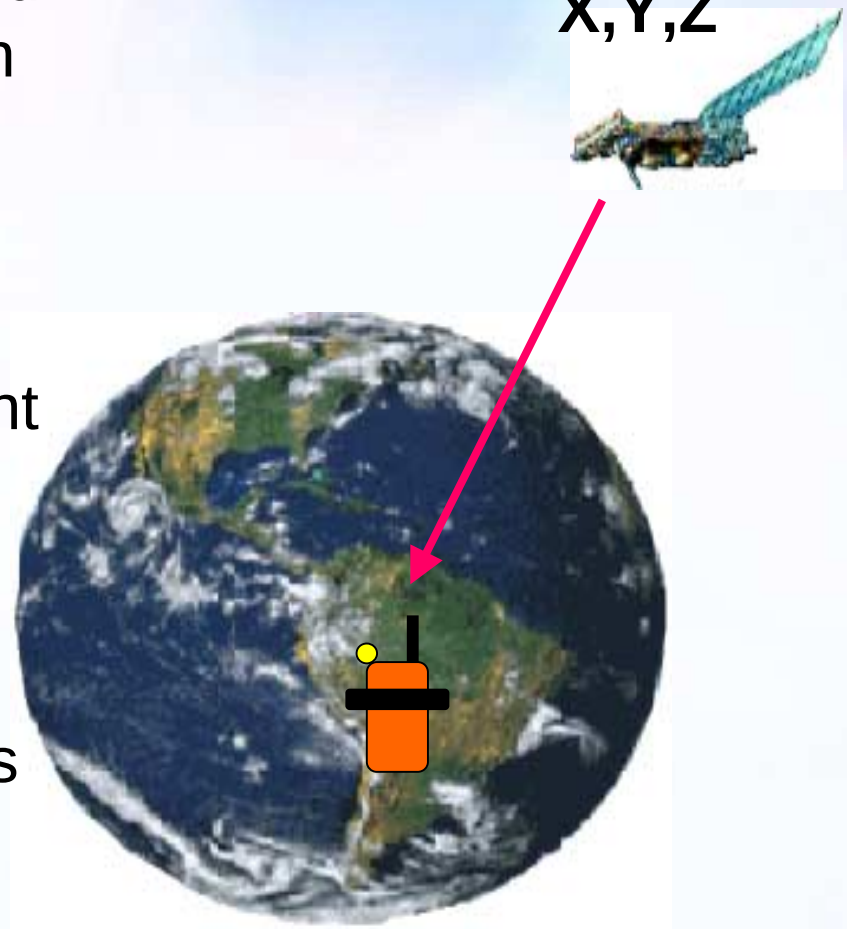
Determining Beacon Locations From LEO Doppler Data



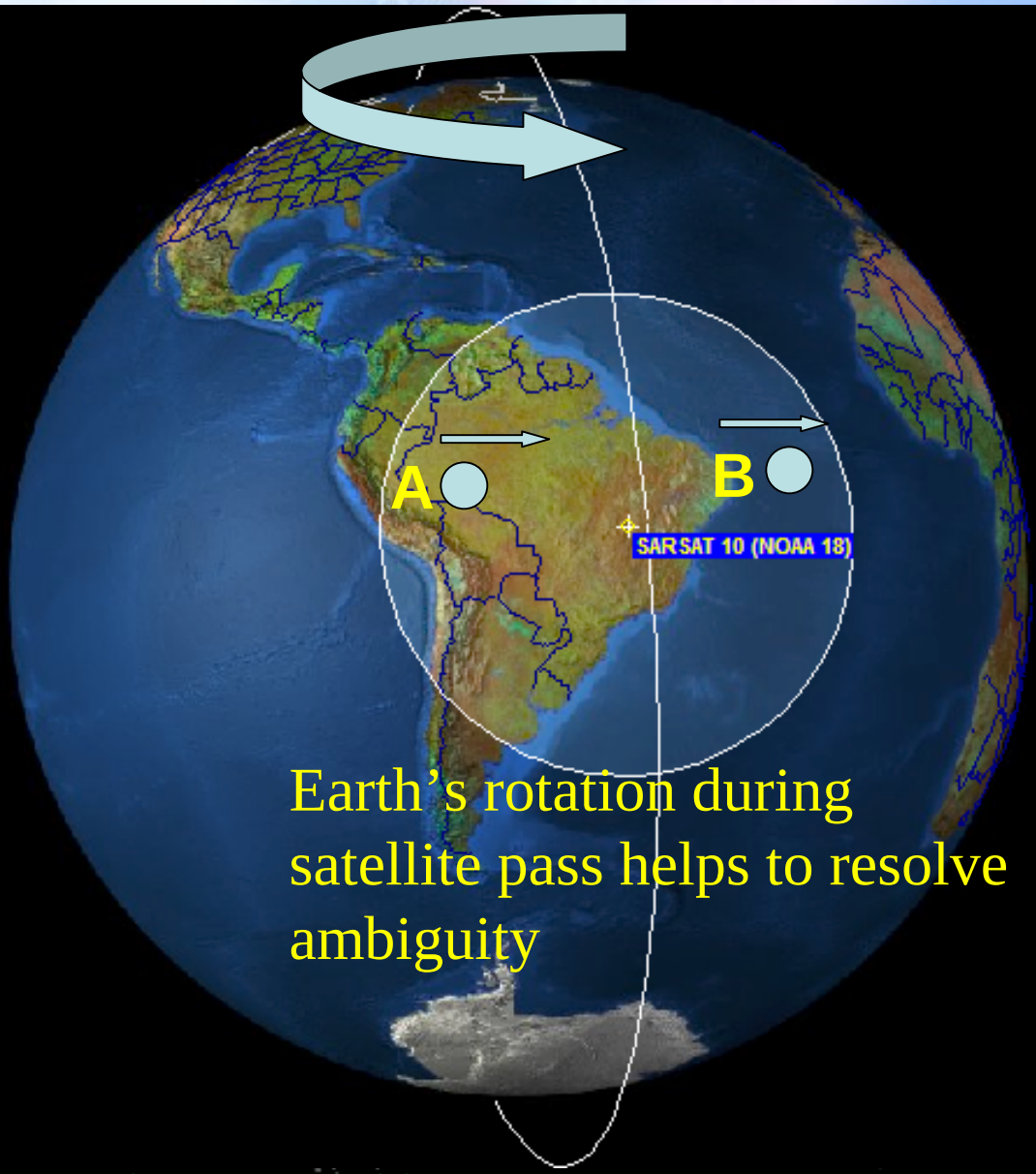


Determining Beacon Locations From LEO Doppler Data

- Beacon location is computed “relative to” satellite position
- LUT must know exact satellite position in space
- 3 ways to know:
  - Satellite orbit data is sent to LUT daily
  - Downlink Doppler
  - Orbitography beacons
- Ambiguity: pairs of locations produced (real & mirror image)



Resolving Ambiguity



Earth's rotation during satellite pass helps to resolve ambiguity

Resolving Ambiguity

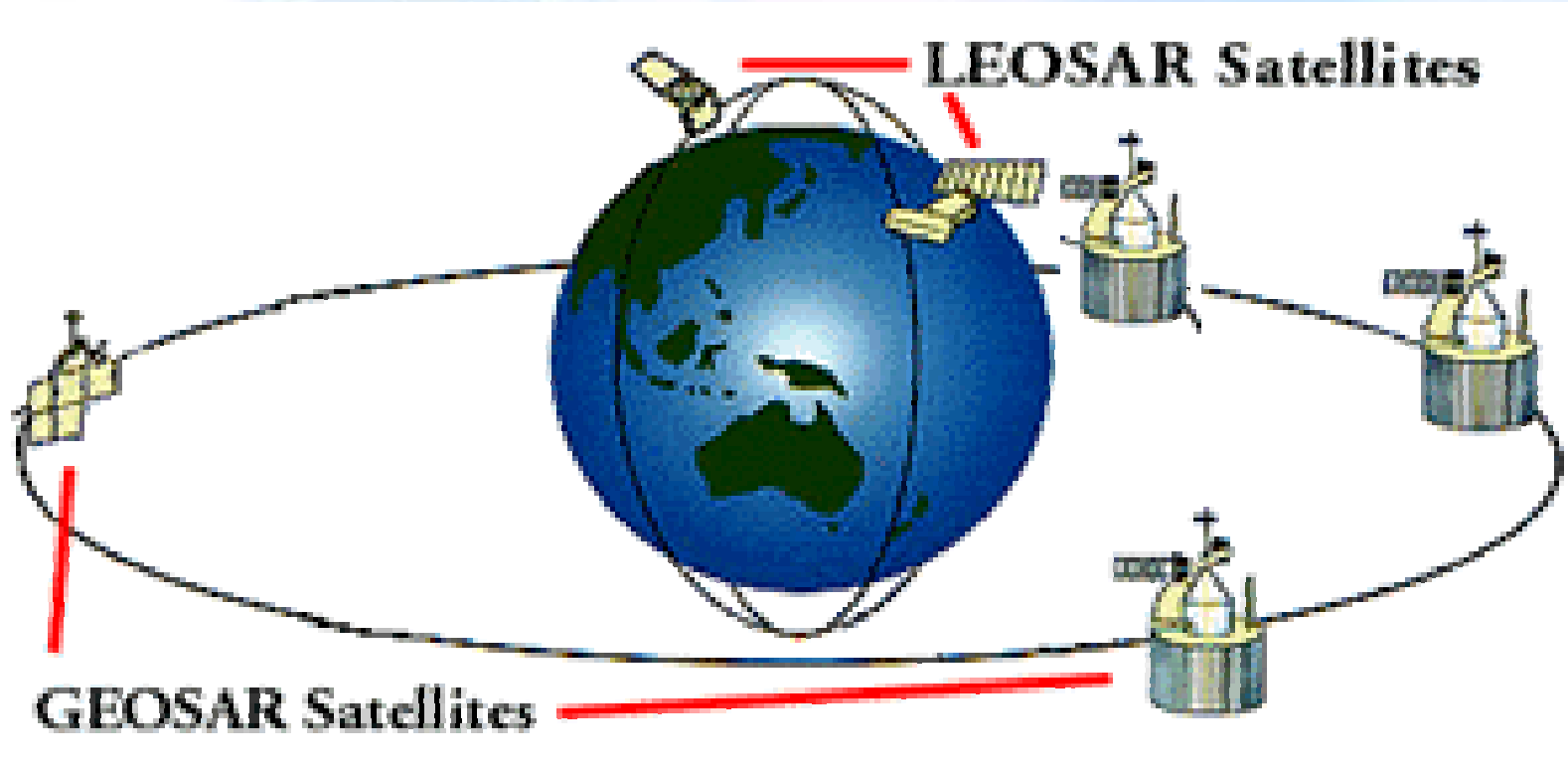
Two Pass Solution for a Beacon Located in Brazil

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

Enhancement: GEOSAR– 1980s



GEOSAR– Experiments mid-1980s

Prototype GEOLUT in 1986

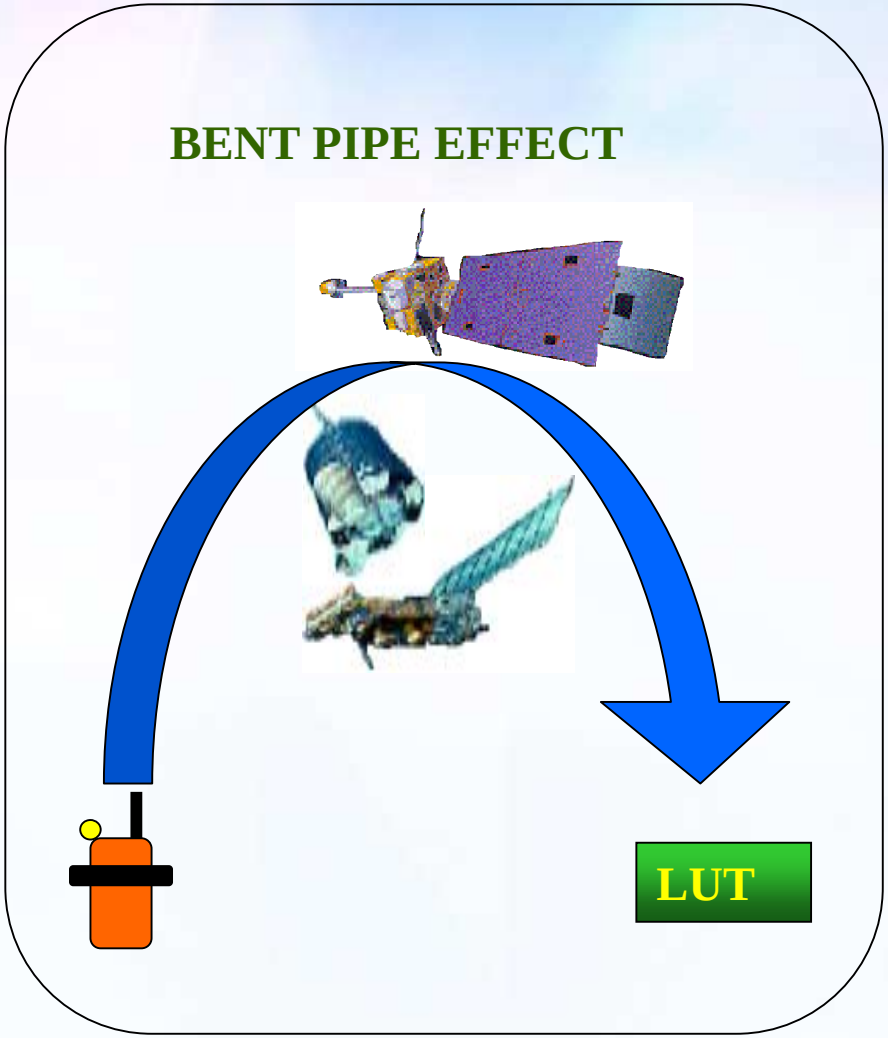
Prototype GEOLUT Processor

Antenna control

Antenna

GEOSAR Repeater

- **GEOSAR Repeaters**
  - **Receive at 406 MHz and transmit at 1544.5 MHz.**
  - **No processing is performed.**

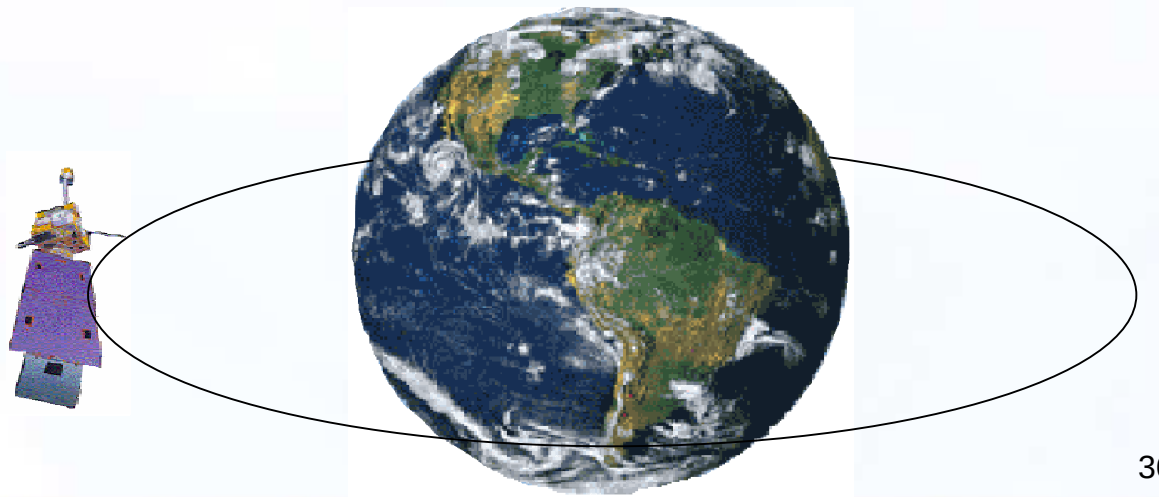


Space Segment Providers and On-Board Instruments

- **GEO Space Segment and Instrument Providers**
  - **U.S. – GOES (East and West) – Repeater**
  - **India – INSAT-3A – Repeater**
  - **Europe – MSG – Repeater**
  - **Russia – planned: Electro-L and Luch-M – Repeater**

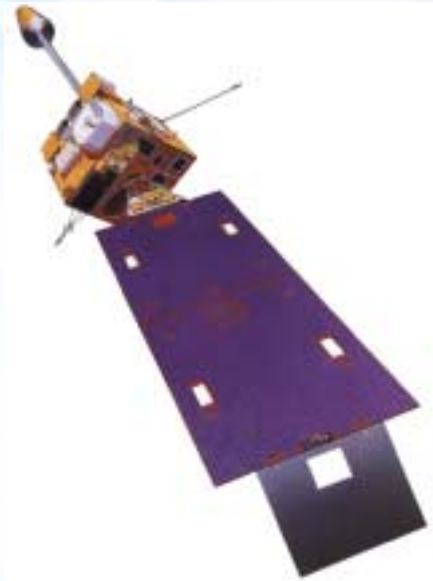
GEOSAR Satellites

- At a fixed point 36,000 km above the Earth's surface
- Continually monitors a large area of Earth's surface
- Covers up to +/- 75^{o} latitude
- Presently have 4 operational (GOES-E, GOES-W, INSAT-3A, and MSG)



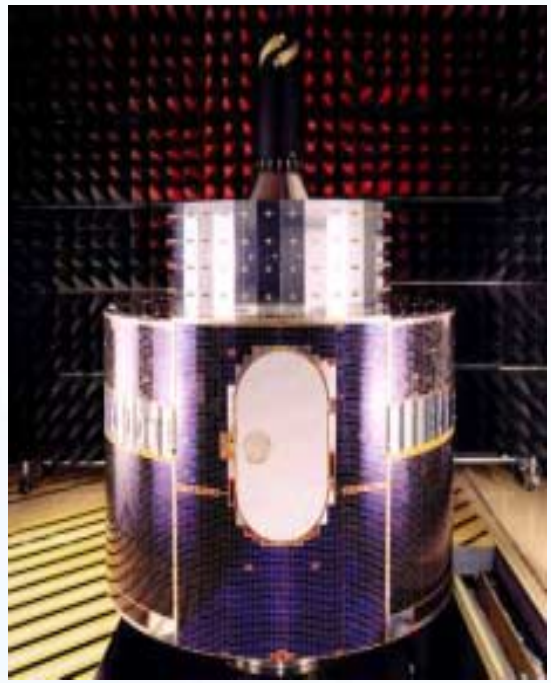
GEOSAR Satellites

Indian National Satellite (INSAT)



Geostationary Operational and Environmental Satellite (GOES)

Meteosat Second Generation (MSG)

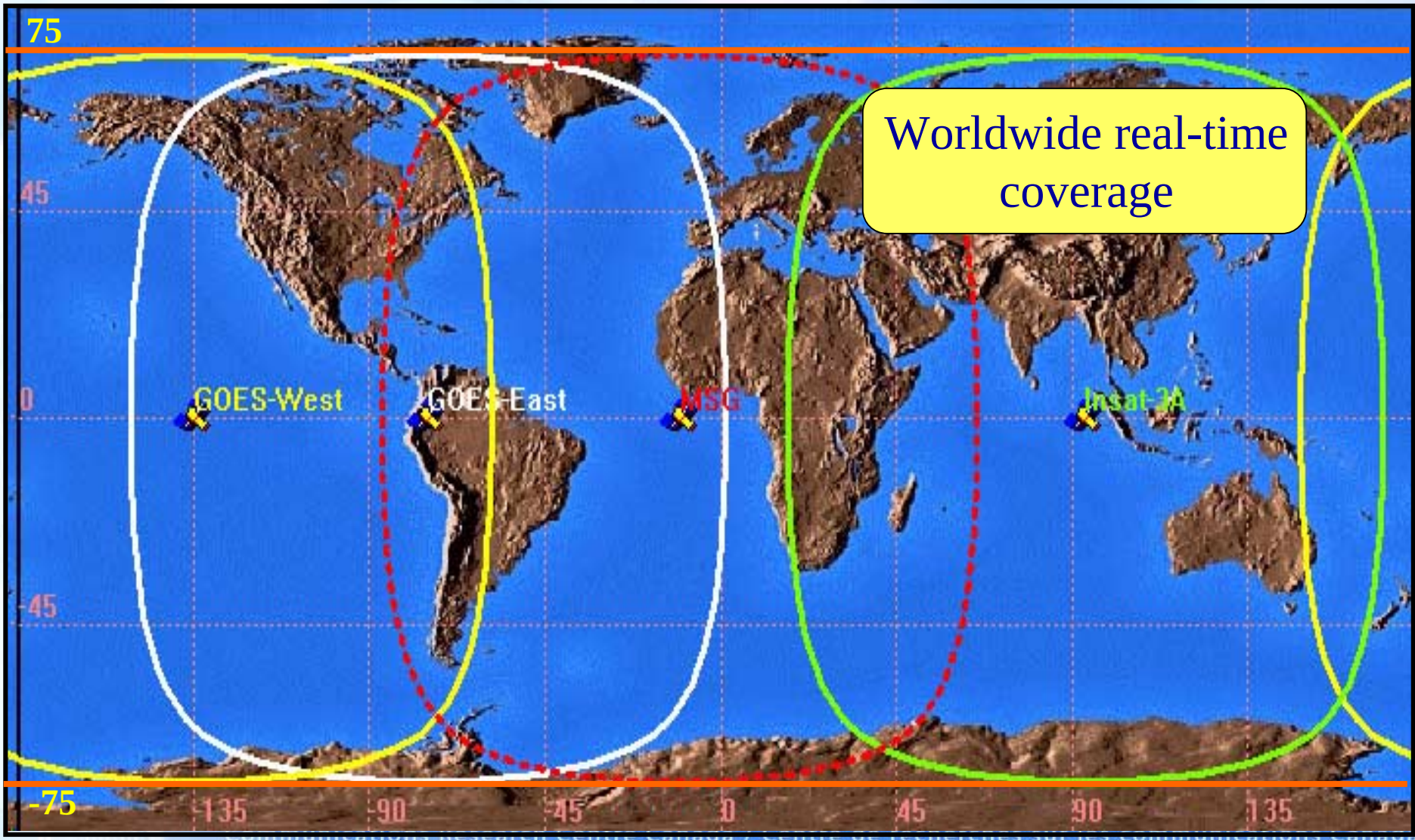


GEO Satellite and SAR Instrument

MSG Satellite

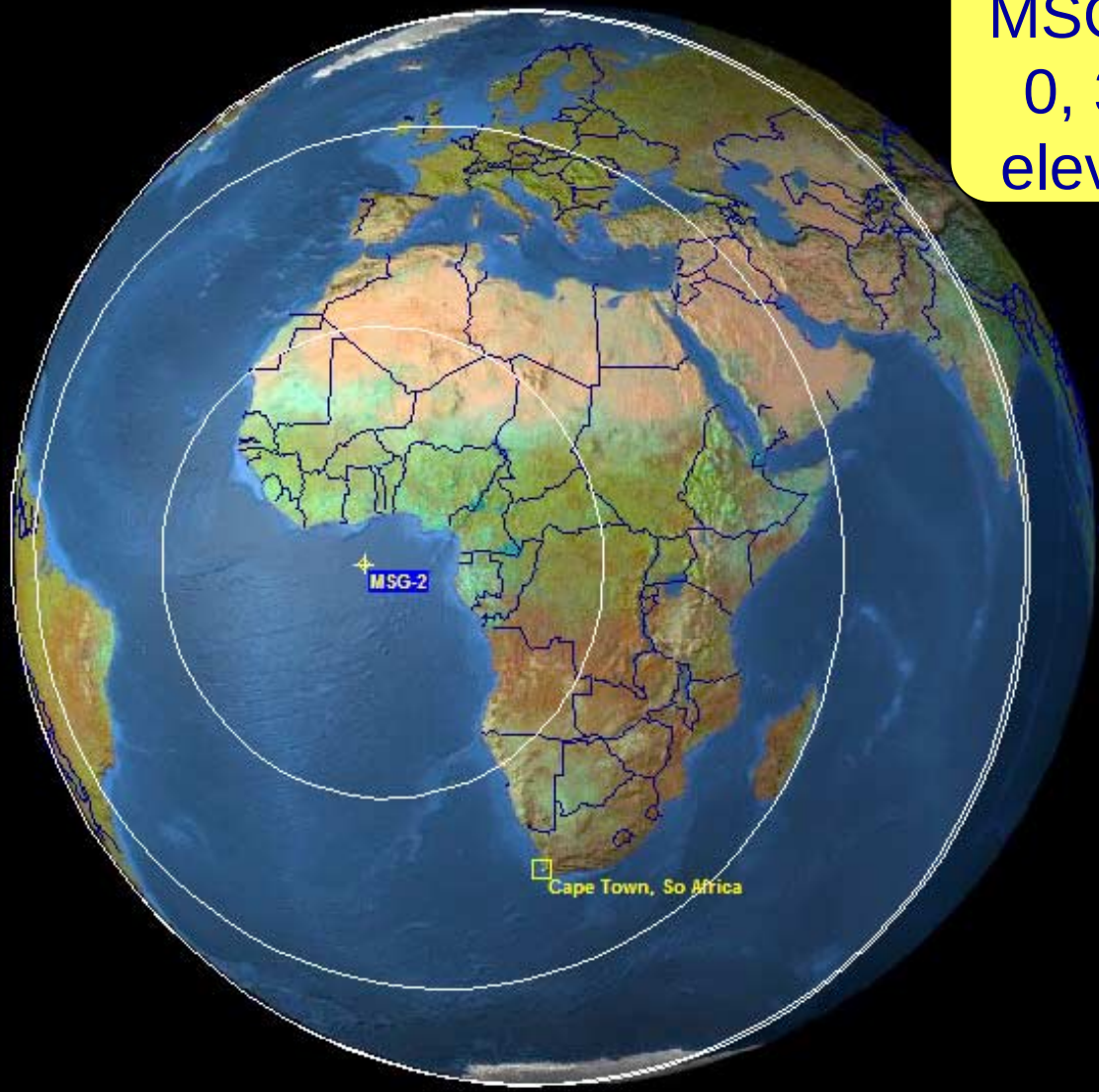
SAR Instrument

GEOSAR Coverage

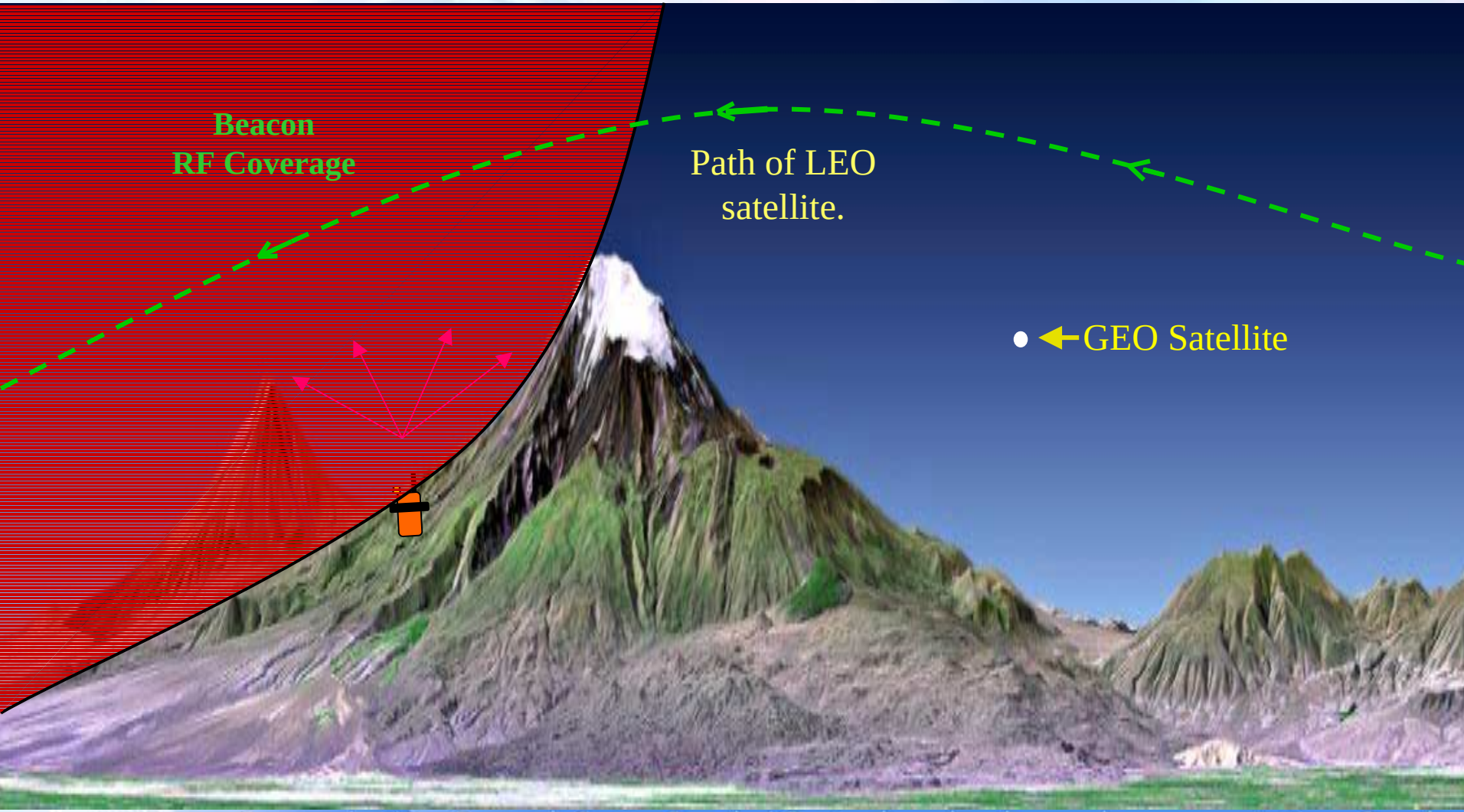


MSG GEOSAR Coverage

MSG footprint for 0, 30 & 60 deg elevation angles

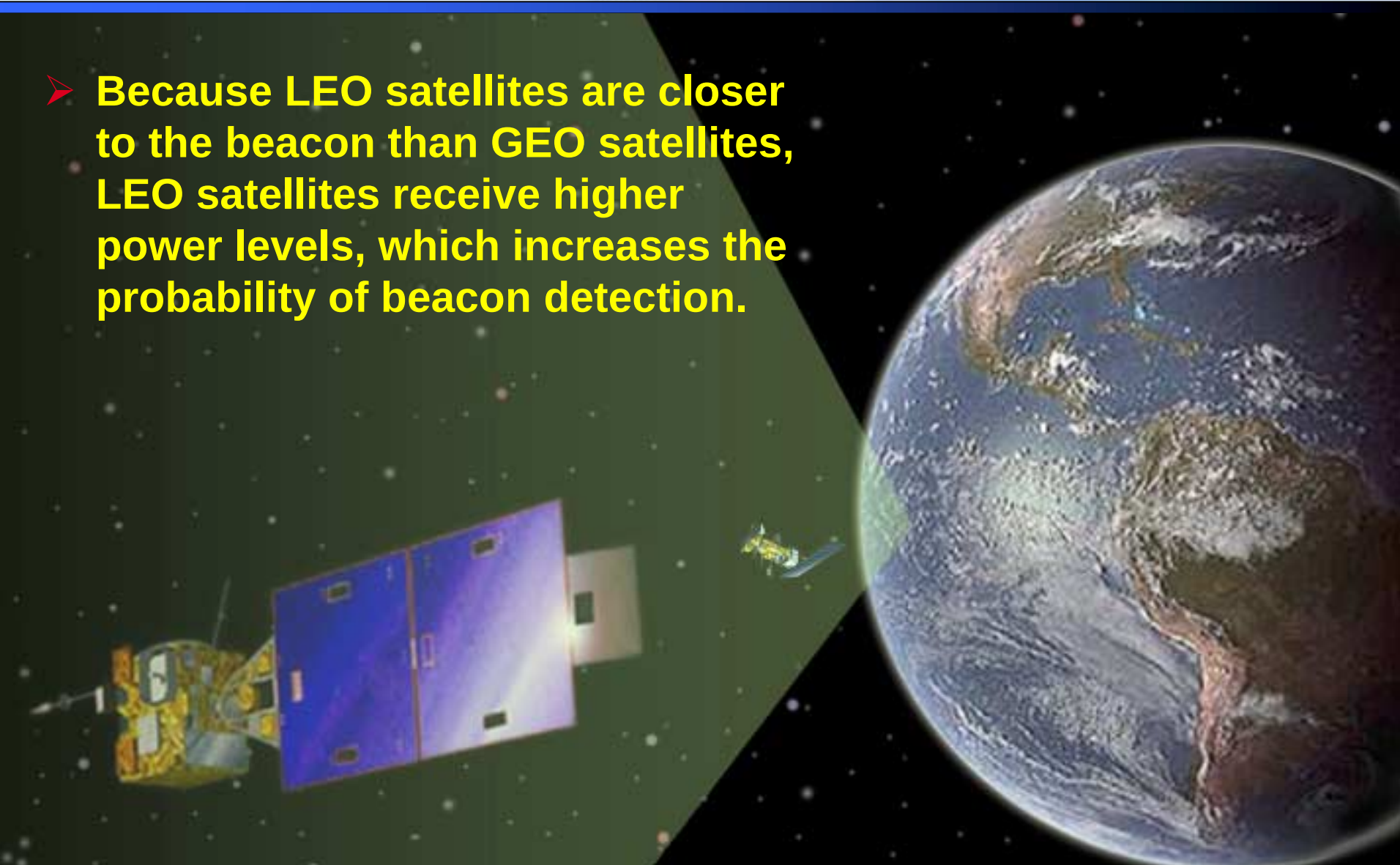


Beacon Detection with Obstruction

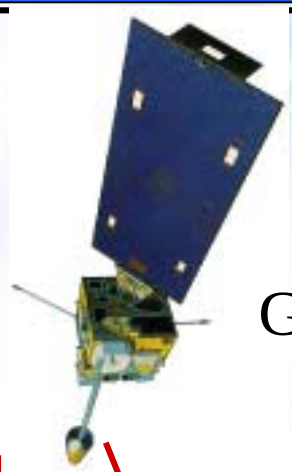


Beacon Power Levels with Distance

- Because LEO satellites are closer to the beacon than GEO satellites, LEO satellites receive higher power levels, which increases the probability of beacon detection.



GEOSAR Usually Reports Detection First



GEOSAR

LEOSAR

GEOSAR has a 46 minute mean time advantage over the LEOSAR system

46 Minutes

Time

Regular Distress Beacons

C/S Satellites

406 MHz Message with ID only

A79F0 9F45D D64D0

country code, beacon type, beacon number

Use of GNSS in Location Protocol Beacons

GNSS signals

(GPS, Glonass, Galileo)

C/S Satellites

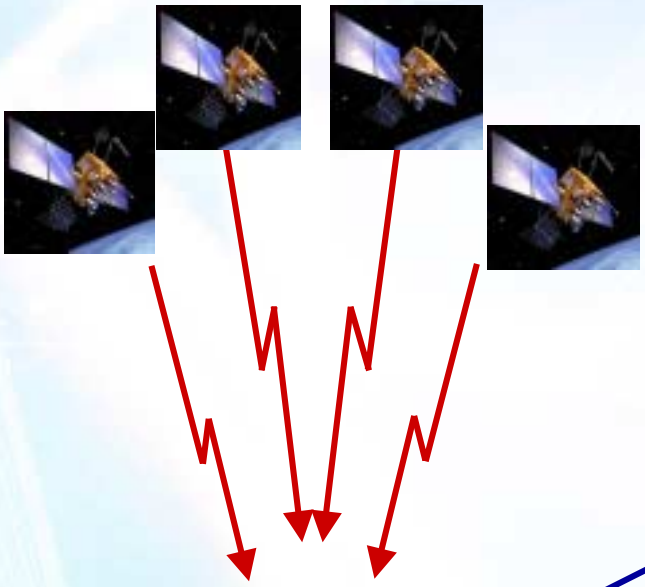
406 MHz Message with ID PLUS Location

A79F0 9F45D D64D0 372DE425

country code, beacon type, beacon number **+Lat, Long,…**

Use of GNSS in Location Protocol Beacons

4 GPS Satellites



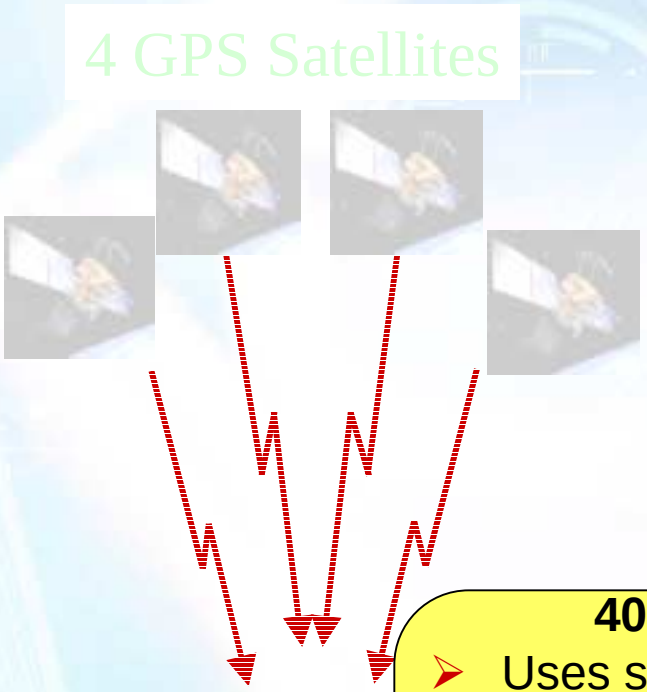
406 MHz Message with Embedded GPS location

C/S Satellites

LUT

20% of beacons are Location Protocol

Use of GNSS in Location Protocol Beacons



GPS Satellites

- 24-satellite constellation
- 4 satellites in view at all times
- Minimum of 3 satellites needed to compute locations. Additional satellites improve accuracy.
- Transmit time and orbital data

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.
- It can take several minutes to calculate first location after turning on GPS
- It then encodes location in 406 MHz message.

Advantages of LEOSAR System over the GEOSAR System

- Locates beacons using Doppler shift processing. GEOSAR system does not have Doppler capability.
- Detects and locates 121.5 MHz signals.
- Locates 406 MHz beacons. GEOSAR system only detects 406 MHz beacons.
- Provides global coverage for 406 MHz. GEOSAR system does not cover the polar areas.
- Provides improved detection probability for obstructed beacons.
- Receives higher power levels from beacons, which increases the probability for beacon detection.

Advantages of GEOSAR System over the LEOSAR System

GEOSAR only for 406 MHz beacons:

- **Near instantaneous detection.**
- **Near instantaneous location for beacons with GPS capacity**
- **Continuous monitoring of 1/3 of Earth's surface**
- **Has a 46 minute mean time advantage for first detections**

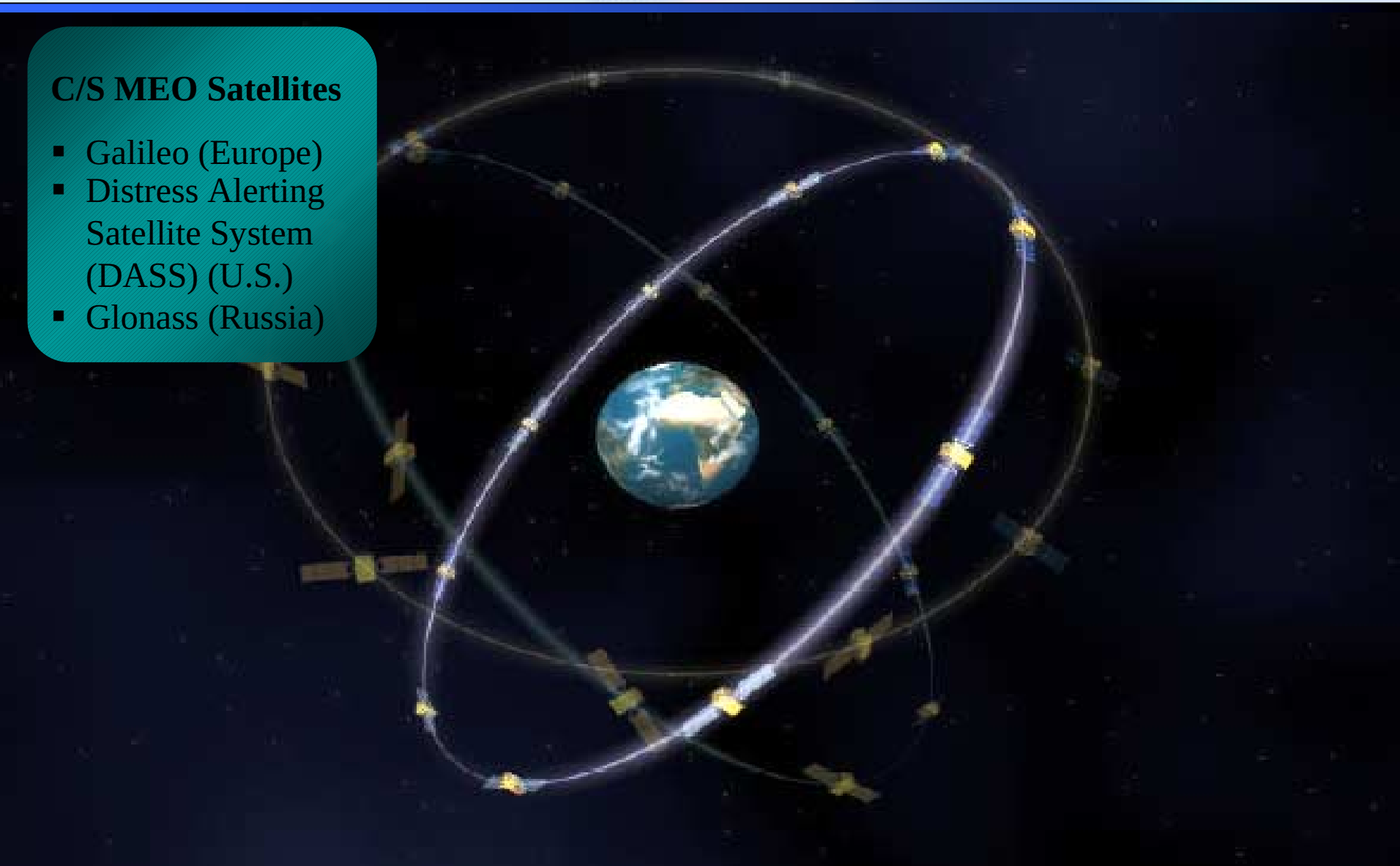
Future LEO & GEO Launches

- More LEO and GEO payloads are ready for launch
- More are being built for service for next decade

Next Cospas-Sarsat Enhancement : MEOSAR System

C/S MEO Satellites

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



Thank You