Satellite-Aided Search & Rescue (SAR) Systems — Reference Guide

COSPAS-SARSAT International Programme and supplemental commercial systems. Covers LEOSAR, GEOSAR, MEOSAR, and commercial SAR satellite constellations; beacon types (EPIRB, ELT, PLB); and the ground/protocol architecture. Compatible with 406 MHz EPIRB, ELT, and PLB beacon standards. Sources: COSPAS-SARSAT.int, NOAA SARSAT, ESA, CNES, Wikipedia.

System Architecture Overview

COSPAS-SARSAT — The Global SAR Satellite Programme

Founded 1979 by Canada, France, the United States, and the Soviet Union; treaty signed 1988. Now 45 member nations. Detects and locates 406 MHz digital distress beacons (EPIRB, ELT, PLB) anywhere on Earth and forwards alerts to Rescue Coordination Centers (RCCs) at no cost to beacon users. Since 1982 has assisted in the rescue of over 60,000 people. Operates three complementary satellite layers: LEOSAR, GEOSAR, and MEOSAR.

LEOSAR (Low Earth Orbit SAR) — ~850–1,000 km altitude

Original architecture. Polar-orbiting satellites detect 406 MHz beacons via Doppler frequency shift and compute position to within 1–5 km. Store-and-forward capability provides global coverage including polar regions. Latency up to 90 minutes at equator; near-immediate at poles. SARP (onboard processor) computes Doppler position; SARR (repeater) relays signal in real time when ground station is in view. Gradually being supplemented by MEOSAR.

GEOSAR (Geostationary Orbit SAR) — ~35,786 km altitude

Introduced in 1987 (GOES-7). GEO satellites carry 406 MHz SARR repeaters and provide near-instantaneous alerting (seconds to minutes). Cannot compute Doppler position due to fixed orbit — relies on GPS position embedded in modern beacon message. Coverage 70°N to 70°S; no polar coverage. 9+ active GEOSAR satellites spanning the global ring. Best used with GPS-enabled beacons for fast alert + position.

MEOSAR (Medium Earth Orbit SAR) — ~19,000–24,000 km altitude

Newest architecture (development began 2004; operational 2016). SAR payloads hosted on GPS (USA), GLONASS (Russia), Galileo (Europe), and BeiDou (China) navigation constellations. Multiple satellites simultaneously in view of any beacon, providing near-instantaneous detection AND independent Doppler position (1–2 km accuracy) without needing GPS in beacon. Galileo additionally provides Return Link Service (RLS) — confirms receipt of distress signal back to the beacon. Will eventually replace LEOSAR as primary architecture once global MEOLUT ground segment is complete.

Beacon Types Supported

EPIRB (Emergency Position-Indicating Radio Beacon): maritime vessels. Auto-activates on water immersion. | ELT (Emergency Locator Transmitter): aviation. Auto-activates on impact (G-switch) or manually. ELT(DT) variant transmits in-flight before crash. | PLB (Personal Locator Beacon): individuals; hiking, wilderness, small craft. Manual activation only. All modern versions operate on 406 MHz digital frequency with unique HEX ID code enabling registration lookup. Analog 121.5 MHz phased out of satellite processing Feb 1, 2009.

COLOR KEY — System / Orbit Type

LEOSAR — Low Earth Orbit SAR		GEOSAR — Geostationary Orbit SAR	
MEOSAR — Medium Earth Orbit SAR		Heritage / Pre-COSPAS Systems	
Supplemental / Commercial SAR			

System Type	Provider / Country	Satellite / Program	Active Period	# Satellites	Orbit	Frequency / Technology	Beacon Types Supported	Notes
HERITAGE	USA	**ELT 121.5 MHz Analog Network (pre-satellite)**	1972 – 2009 (satellite phase-out)	N/A (ground-based detection)	N/A — ground and aircraft intercept only	121.5 MHz / 243.0 MHz analog	ELT (aviation)	Mandated by U.S. Congress in 1973 after 1972 loss of Rep. Boggs/Begich aircraft in Alaska. Analog ELTs transmitted a tone-only signal — no unique ID, no position data. >98% of all alerts were false. Detection range very limited; required line-of-sight from search aircraft or passing airline. Never satellite-capable by design. 121.5 MHz satellite processing terminated Feb 1, 2009 by COSPAS-SARSAT Council per IMO/ICAO guidance.

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HERITAGE	Russia	**Cosmos 1383 — First COSPAS Satellite**	Jun 1982 – Decommissioned	1 (COSPAS-1 payload)	LEO polar, ~1,000 km, ~83° incl.	121.5 / 243 / 406 MHz	ELT, EPIRB	First COSPAS satellite — Soviet contribution to the joint program. Launched June 30, 1982. First-ever satellite-aided SAR rescue occurred just 10 weeks later on Sep 9, 1982: aircraft crash in British Columbia. Three survivors rescued. Designated COSPAS-1 (SARSAT payload numbering used for U.S. satellites). Proved the concept that would become the permanent international system.
HERITAGE	USA	**NOAA-8 — First SARSAT Satellite (USA)**	Mar 1983 – 1985 (SAR ops)	1 (SARSAT-1 payload)	LEO SSO, ~830 km, ~98.7° incl.	121.5 / 243 / 406 MHz	ELT, EPIRB, PLB	First U.S. SARSAT satellite. Launched March 28, 1983. SARSAT instrument (SARP/SARR) provided by Canada and France riding as secondary payload on NOAA weather satellite. Demonstrated both 121.5 MHz and 406 MHz detection. Partnered with Soviet COSPAS satellites to create the combined system. System declared fully operational in 1985. First marine rescue: trimaran 'Gonzo', Oct 1983, 300 nm east of Boston.
LEOSAR	USA / Canada / France	**NOAA POES / SARSAT Series (SARSAT-1 through SARSAT-14)**	1983 – Present (MetOp-B/C active; NOAA-19 active)	~14 SARSAT payloads; 3–4 active at any time	LEO SSO, ~830–870 km, ~98–99° incl.; ~102 min orbit	406 MHz (SARP-3); legacy 121.5 MHz phased out 2009	ELT, EPIRB, PLB	Backbone of LEOSAR. NOAA POES satellites (NOAA-8 through NOAA-19) each carry SARSAT instruments (SARP Generations 1–3). SARP-1/2 on NOAA-8 through NOAA-15; SARP-3 introduced on MetOp-A (2006). SARP detects 406 MHz beacons, computes Doppler-derived position. Store-and-forward capability for global coverage. Canada supplied SARP instruments; France provided timing reference. NOAA-19 (2009) and MetOp-B/C currently primary LEOSAR assets.
LEOSAR	Russia	**COSPAS Series — Nadezhda / Sarsat-compatible satellites (COSPAS-1 through COSPAS-13)**	1982 – ~2013 (Nadezhda); ongoing via Russian contribution	~13 COSPAS payloads; currently reduced to 1–2 active	LEO polar, ~1,000 km, ~83° incl.; ~105 min orbit	406 MHz; legacy 121.5/243 MHz prior to 2009	ELT, EPIRB, PLB	Russian COSPAS satellites were initially the primary LEO component. Nadezhda series (navigation + SAR) carried COSPAS instruments. Higher altitude (~1,000 km vs. U.S. ~850 km) gives larger footprint but less precise Doppler. COSPAS-10 on Nadezhda-7 (2002) was last major Russian LEOSAR addition. Russian LEOSAR contribution has gradually declined; MEOSAR/GLONASS now primary Russian role. Complementary inclination to NOAA satellites reduced coverage gaps.
LEOSAR	Europe (ESA/EUMETSAT)	**MetOp-A / MetOp-B / MetOp-C (SARSAT-12/13/14)**	Oct 2006 – Present (MetOp-B/C active; MetOp-A decommissioned 2021)	3 satellites (1 per MetOp; B and C operationally active)	LEO SSO, ~817 km, ~98.7° incl.; LTAN 09:30	406 MHz (SARP-3 — most capable LEOSAR processor)	ELT, EPIRB, PLB	EUMETSAT MetOp series replaced aging NOAA POES as primary European LEOSAR. SARP-3 (first on MetOp-A) is the most advanced LEOSAR processor — onboard computation of Doppler position before downlink. MetOp-B (2012) and MetOp-C (2018) currently the highest-performing LEOSAR satellites. Continuous SSO coverage; morning and afternoon planes. MetOp Second Generation (MetOp-SG) will carry SARP-3 or successor.
GEOSAR	USA	**GOES-East / GOES-West**	1987 (GOES-7) – Present	2 active GEOSAR	GEO, ~35,786 km; GOES-	406 MHz SARR	ELT, EPIRB, PLB	GOES-7 (1987) first GEOSAR satellite — and first to detect 406 MHz signals from GEO. GEOSAR provides

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		(GOES-R Series: GOES-16, -17, -18)	(GOES-16/18 active)	positions; 9 GOES SAR-capable over program history	East: 75.2°W; GOES-West: 137.2°W	repeater (relay only — no Doppler processing)		near-immediate alerting (seconds to minutes vs. up to 90 min for LEOSAR) but cannot compute Doppler position — relies on GPS-encoded position in beacon message or LEOSAR for location. GOES-East and GOES-West cover most of Western Hemisphere. GOES-R (16/17/18) current generation. GOES-U launched 2024, carries SARR payload. GEOSAR coverage: approx. 70°N to 70°S.
GEOSAR	Europe (ESA/EUMETSAT)	**Meteosat MSG Series (MSG-1 through MSG-4 / Meteosat-8 through -11)**	2002 – Present (MSG-3/4 active)	4 MSG satellites; 2 active GEOSAR positions	GEO, ~35,786 km; primary: 0° and 9.5°E	406 MHz SARR repeater	ELT, EPIRB, PLB	EUMETSAT Meteosat Second Generation (MSG) satellites carry 406 MHz GEOSAR repeaters, extending coverage over Europe, Africa, and the Indian Ocean. MSG-3 (0°) and MSG-4 (9.5°E or backup) operationally active. Covers areas out of GOES reach. Meteosat Third Generation (MTG) series will continue GEOSAR mission. Part of multi-national GEOSAR complementary coverage network.
GEOSAR	Russia	**Elektro-L Series (Elektro-L1, -L2, -L3)**	2011 – Present (L2/L3 active)	3 satellites; 2 active GEOSAR positions	GEO, ~35,786 km; 76°E (L1/L2), 165.8°E (L3)	406 MHz SARR repeater	ELT, EPIRB, PLB	Russian geostationary weather/GEOSAR satellite. Elektro-L1 (2011) at 76°E replaced older GOMS system. Elektro-L2 (2015) and Elektro-L3 (2019) followed. Provides GEOSAR coverage over Russia, Central Asia, and Indian Ocean sector. Elektro-L3 at 165.8°E extends coverage toward Pacific. Part of the global GEOSAR ring.
GEOSAR	India	**INSAT-3A / INSAT-3D / INSAT-3DR**	2003 – Present (INSAT-3D/3DR active)	3 satellites (2 active for SAR)	GEO, ~35,786 km; 93.5°E (3A/3D); 74°E (3DR)	406 MHz SARR repeater	ELT, EPIRB, PLB	ISRO Indian geostationary weather satellites carrying GEOSAR payloads. INSAT-3A (2003) first Indian GEOSAR asset. INSAT-3D (2013) and INSAT-3DR (2016) current operational assets. Cover Indian subcontinent, Arabian Sea, Bay of Bengal, and surrounding Indian Ocean region — a critical SAR gap-fill for maritime traffic in that sector. India operates the Lucknow GEOLUT ground station.
GEOSAR	Japan	**MTSAT / Himawari-8 / Himawari-9**	2006 (MTSAT-2) – Present (Himawari-8/9 active)	3 satellites (2 active)	GEO, ~35,786 km; 140°E	406 MHz SARR repeater	ELT, EPIRB, PLB	Japan Meteorological Agency GEOSAR assets. MTSAT-2 (2006) carried first Japanese GEOSAR payload. Himawari-8 (2014) and Himawari-9 (2016) carry SARR instruments as secondary payloads. Cover Northwest Pacific, Japan, and Australia/Oceania SAR region. Provide redundancy and overlap with GOES-West for Pacific maritime traffic. Himawari-9 serves as backup while Himawari-8 is primary.
GEOSAR	China	**FY-2 (Fengyun-2) / FY-4 Series**	~2012 – Present	~3 active positions	GEO, ~35,786 km; various 86.5°–112°E positions	406 MHz SARR repeater	ELT, EPIRB, PLB	China Meteorological Administration geostationary weather satellites with secondary GEOSAR payloads. FY-2E/F/G series carried SAR repeaters. FY-4A (2016) and FY-4B (2021) continue the GEOSAR mission. Cover East Asia, South China Sea, and western Pacific. China's GEOSAR contribution is part of the global COSPAS-SARSAT cooperative; ground

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								data flows through China's GEOLUT and MCC to international system.
MEOSAR	USA	**GPS Block IIR / IIF / IIIA — DASS (Distress Alerting Satellite System)**	2004 (experimental) – Present (operational)	18 GPS IIR/IIF (experimental DASS) + 4 GPS IIIA (operational); GPS IIIF (~2026, dedicated L-band)	MEO circular, ~20,200 km, ~55° incl.; 12-hour orbit	406 MHz S-band (IIR/IIF experimental); L-band (IIIA/IIIF operational); near-real-time	ELT, EPIRB, PLB	GPS-hosted MEOSAR component. DASS repeaters provided by Canada as secondary payload on GPS satellites. GPS Block IIR/IIF carry experimental S-band SAR repeaters; GPS IIIA (SV01/03/04/05) carry first operational L-band MEOSAR payloads. GPS IIIF (~2026 onward) will carry dedicated, Canada-provided operational L-band SAR instruments. 24+ GPS satellites in 6 orbital planes provide near-global, near-instantaneous coverage. Key advantage: multiple satellites simultaneously in view of any beacon.
MEOSAR	Russia	**GLONASS-K1 / GLONASS-K2 — SAR Payload**	2011 (K1 experimental) – Present	~8 GLONASS satellites with SAR payloads (K1 and K2 series)	MEO circular, ~19,130 km, ~64.8° incl.; ~11.3-hour orbit	406 MHz L-band MEOSAR repeater; near-real-time	ELT, EPIRB, PLB	Russian MEOSAR contribution via GLONASS navigation constellation. GLONASS-K1 (first launched 2011) carried first Russian MEO SAR payload. GLONASS-K2 series adds improved SAR capability. The 64.8° orbital inclination provides excellent coverage of high-latitude regions (Arctic, sub-Arctic) that are outside GEOSAR reach but critical for polar maritime and aviation SAR. Russia's GLONASS fleet contributes multiple SAR-capable satellites providing redundant polar coverage.
MEOSAR	Europe (ESA/EUMETSAT)	**Galileo FOC / SAR-Galileo (incl. Return Link Service)**	2016 (operational declaration) – Present	~22 Galileo FOC satellites with SAR payloads; growing constellation	MEO circular, ~23,222 km, ~56° incl.; ~14.1-hour orbit	406 MHz L-band MEOSAR; near-real-time + Return Link Service (RLS) downlink to beacon	ELT, EPIRB, PLB; RLS-capable beacons	European MEOSAR and world's first Return Link Service (RLS) provider. SAR Galileo declared operational 2016; RLS (confirmation signal back to beacon) declared operational 2020. RLS is a unique Galileo capability — it acknowledges to the distressed person that their signal was received, reducing uncertainty. Managed by CNES on behalf of European Commission. Ground stations at 4 SAR-Galileo LUTs in Europe and Réunion Island. Full Galileo constellation (30 satellites) provides highest-density MEOSAR coverage.
MEOSAR	China	**BeiDou-3 (BDS-3) — SAR Payload**	2020 (BDS-3 full constellation declared) – Present	~3 BDS-3 MEO satellites with SAR payloads (growing)	MEO circular, ~21,528 km, ~55° incl.; ~12.9-hour orbit	406 MHz MEOSAR repeater	ELT, EPIRB, PLB	China's BeiDou-3 navigation constellation contributes to MEOSAR. BDS-3 satellites carry secondary SAR repeater payloads as part of China's contribution to COSPAS-SARSAT. Integration into the international system still maturing as of 2025. BDS-3 MEO constellation (24 satellites) at ~55° inclination complements GPS/Galileo/GLONASS geometries. China also operates GEO and IGSO BDS satellites which extend regional SAR-related coverage.
COMMERCIAL/ SUPPLEM.	Commercial	**Iridium NEXT — GMDSS and Commercial SAR**	2017 (launch complete) – Present	66 LEO satellites + 6 spares	LEO, ~780 km, ~86.4° incl. (near-polar); 11 orbital planes	406 MHz SAR relay (partial); Iridium 9-line GMDSS; L-band voice/data	EPIRB (Iridium-GMDSS), PLB, Iridium communicators	Iridium NEXT satellites carry secondary GMDSS (Global Maritime Distress and Safety System) and partial SAR relay capability. True polar coverage (86.4° incl.) fills geographic gaps in GEOSAR. Iridium-linked EPIRB/PLB devices provide 2-way messaging — distressed person can exchange text with RCC.

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								IMO approved Iridium as GMDSS provider 2020. Not part of official COSPAS-SARSAT 406 MHz system but provides complementary global coverage especially in polar regions.
COMMERCIAL/ SUPPLEM.	Commercial	**Globalstar — SPOT / GEOS Satellite Network**	1999 (1st gen) / 2010 (2nd gen) – Present	48 LEO satellites (2nd gen) + 4 ground spares	LEO, ~1,414 km, ~52° incl.; 8 orbital planes	L-band (1.6 GHz); proprietary messaging; not 406 MHz COSPAS-SARSAT	SPOT PLB devices, GEOS tracking	Globalstar constellation supports commercial personal SAR/tracking products (SPOT series, GEOS). NOT compatible with the official COSPAS-SARSAT 406 MHz system — uses proprietary L-band protocol. SPOT devices activate distress alerts routed through Globalstar ground network to GEOS International Emergency Response Center (IERCC), then to local SAR authorities. 52° inclination limits polar coverage. 2nd-generation constellation (Globalstar-2) launched 2010–2013 improves reliability.
COMMERCIAL/ SUPPLEM.	Commercial	**Garmin inReach / Iridium Satellite Network**	2012 (inReach launch) – Present	66 Iridium NEXT LEO satellites (shared)	LEO, ~780 km, ~86.4° incl. (Iridium network)	L-band; 2-way messaging; not 406 MHz COSPAS-SARSAT	Personal PLB-equivalent (inReach), satellite communicators	Garmin inReach (formerly DeLorme SPOT competitor) uses Iridium NEXT network. Provides 2-way messaging, SOS alerting, GPS tracking. SOS routed through GEOS IERCC. Not a COSPAS-SARSAT 406 MHz device but widely used as PLB supplement/alternative by hikers, adventurers, and mariners. Near-global coverage via Iridium. inReach SE and Mini variants widely carried by emergency management professionals.
COMMERCIAL/ SUPPLEM.	Multi / COSPAS-SARSAT	**Return Link Service (RLS) via SAR Galileo**	Nov 2020 (declared operational) – Present	22+ Galileo FOC satellites (shared with SAR-Galileo)	MEO, ~23,222 km, ~56° incl. (Galileo constellation)	406 MHz L-band downlink to beacon (RLS confirmation signal)	RLS-capable 406 MHz beacons (2nd-gen beacons)	First-ever capability to acknowledge a distress signal back to the beacon. When a 2nd-generation 406 MHz beacon activates, a brief RLS confirmation message is encoded in the Galileo navigation data stream and received by the beacon's GNSS receiver. Confirmation indicator on beacon activates, reducing distress person's uncertainty that help is coming. Operated by CNES / European Commission. RLS-capable beacons required to receive confirmation — older beacons transmit but cannot receive.
COMMERCIAL/ SUPPLEM.	USA	**NOAA GOES-R SAR / Next-Gen LEOSAR Planning**	2024 (GOES-U launched) – Present	4 GOES-R series satellites (16, 17/18, U); LEOSAR successor TBD	GEO, ~35,786 km (GOES-R GEOSAR); LEO planned for dedicated LEOSAR successor	406 MHz SARR (GEO relay); dedicated LEO SAR satellite under study	ELT, EPIRB, PLB	GOES-U (2024) continues GEOSAR mission with updated SARR payload. NOAA also studying a dedicated LEO SAR satellite to supplement aging POES/MetOp LEOSAR assets and bridge gap as reliance shifts to MEOSAR. GPS Block IIIF (~2026) will carry Canada-supplied dedicated L-band SAR payloads improving GPS MEOSAR performance. Transition plan: LEOSAR remains operational as MEOSAR ground segment expands globally to handle full MEOSAR load.

Abbreviations: COSPAS = Cosmicheskaya Sistema Poiska Avariynyh Sudov (Space System for Search of Vessels in Distress) | SARSAT = Search and Rescue Satellite-Aided Tracking | LEOSAR = Low Earth Orbit SAR | GEOSAR = Geostationary Orbit SAR | MEOSAR = Medium Earth Orbit SAR | SARP = Search and Rescue Processor (onboard) | SARR = Search and Rescue Repeater (real-time relay) | LUT = Local User Terminal | LEOLUT/GEOLUT/MEOLUT = LUT type for each orbit regime | MCC = Mission Control Centre | RCC = Rescue Coordination Centre | SPOC = SAR Point of Contact | EPIRB = Emergency Position-Indicating Radio Beacon (marine) | ELT = Emergency Locator Transmitter (aviation) | ELT(DT) = ELT for Distress Tracking (in-flight activation) | PLB = Personal Locator Beacon (land/individual) | MSLD = Maritime Survivor Locating Device | RLS = Return Link Service (Galileo acknowledgment back to beacon) | DASS = Distress Alerting Satellite System (GPS SAR component) | GMDSS = Global Maritime Distress and Safety System | IERCC = International Emergency Response Coordination Centre | HEX ID = unique 15-digit hexadecimal beacon identifier | IBRD = International Beacon Registration Database | SSO = Sun-Synchronous Orbit | GEO = Geostationary Orbit | MEO = Medium Earth Orbit | LEO = Low Earth Orbit | 406 MHz = internationally reserved distress frequency | 121.5 MHz = legacy analog homing frequency (still used for close-in direction-finding by rescue aircraft)

System Status Note: As of early 2026, the COSPAS-SARSAT constellation includes ~3 active LEOSAR satellites, ~9 active GEOSAR satellites, and ~49 active MEOSAR satellites (GPS/GLONASS/Galileo/BeiDou). MEOSAR transition is ongoing; full replacement of LEOSAR pending global MEOLUT ground segment completion. Over 60,000 lives saved since 1982.