National Aeronautics and
Space Administration

NASA Search and Rescue SAR Controllers Training

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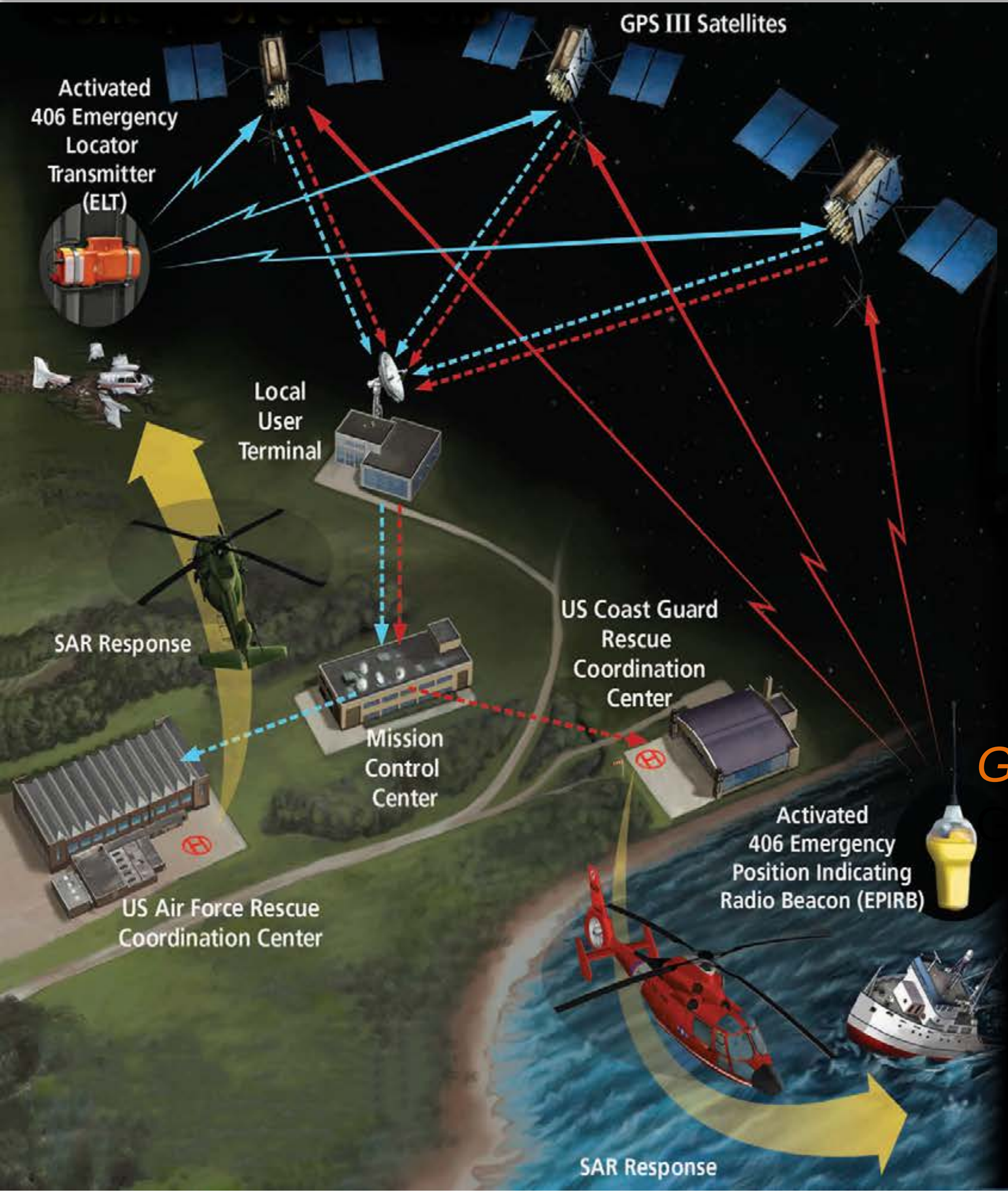
NASA'S ROLE IN SEARCH AND RESCUE

- Innovate and develop new technologies to improve search and rescue hardware for national/international use in emergencies
  - Emergency beacons for use in distress
  - Ground stations that monitor and distribute data to rescue forces
  - Space payloads that detect the emergency signal and relay to Earth
- Technical arm for United States satellite-aided SAR Program (SARSAT)
  - Work with US Coast Guard, Air Force, and National Oceanic and Atmospheric Administration (NOAA)
- Agencies form a delegation and represent USA on international level
  - COSPAS-SARSAT Program
  - 42+ countries work together to obtain full Earth coverage of beacon detections and rescues

MEOSAR Space Segment

MEOSAR CONCEPT OF OPERATIONS

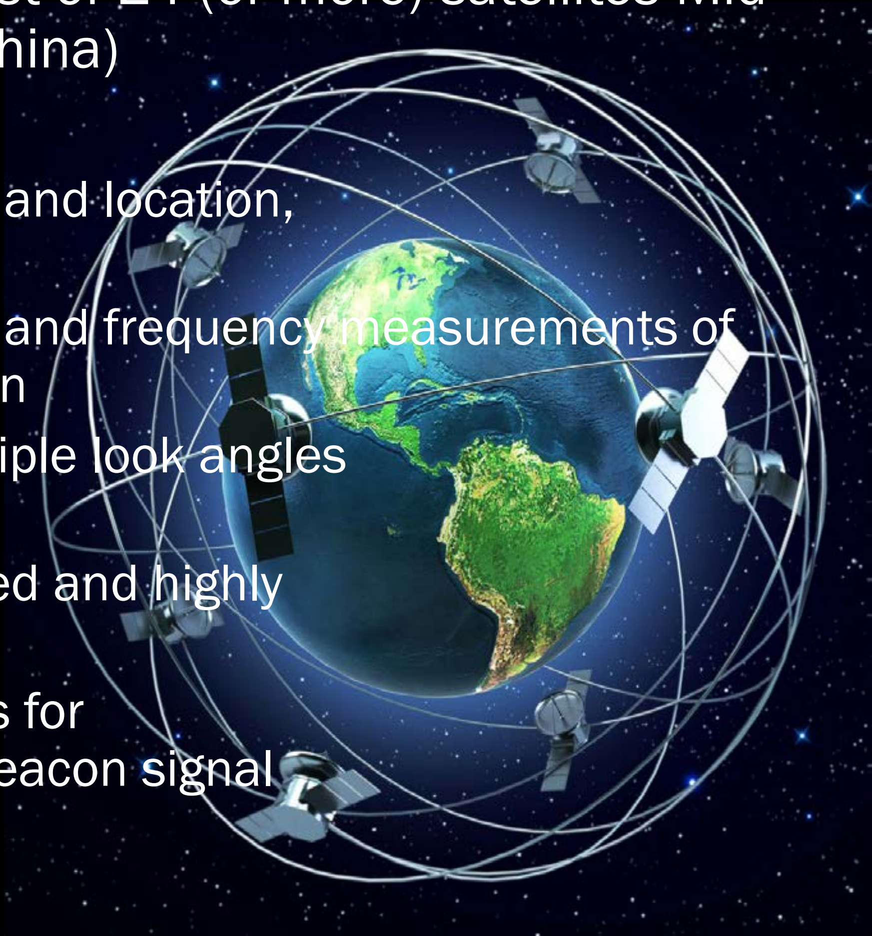


SAR/GPS

Search and Rescue-
Global Positioning Satellite System

MEOSAR: NEXT GENERATION OF SATELLITE-AIDED SAR

- Based on the use of SAR Repeaters carried on board Global Navigation Satellite System (GNSS) satellites
- Global Navigation constellations consist of 24 (or more) satellites Mid Earth Orbit (GPS, Galileo, GLONASS, China)
- Provides
  - Near instantaneous beacon detection and location, globally, at all times
  - Advanced location process using time and frequency measurements of beacon signal to triangulate its location
  - Mitigates terrain blockage due to multiple look angles from multiple moving satellites
  - Robust space segment, well maintained and highly redundant
  - Simple space segment repeater allows for development of higher performance beacon signal



Second Generation Beacons (SGB)

SECOND GENERATION BEACONS

- Capitalize on MEOSAR space segment and improve system performance to meet or exceed C/S requirements, including:
  - Detection probability, location accuracy and system capacity
  - Relax beacon requirements to reduce cost and complexity
  - Collaborate with manufacturers to obtain the most competitive end product
  - RLS: automatic acknowledgment, where return link message sent automatically when location of alert has been confirmed

Increasingly challenging operational requirements that SAR authorities must consider, which include:

- Cancellation function
- On-scene homing
- Return link service

C-S SGBs

Fully realize ability of C-S to provide the gold standard of emergency distress location.

SGB Accuracy Requirement
Determine beacon location within 5 km in first burst 90% of time; 100m after 30 minutes

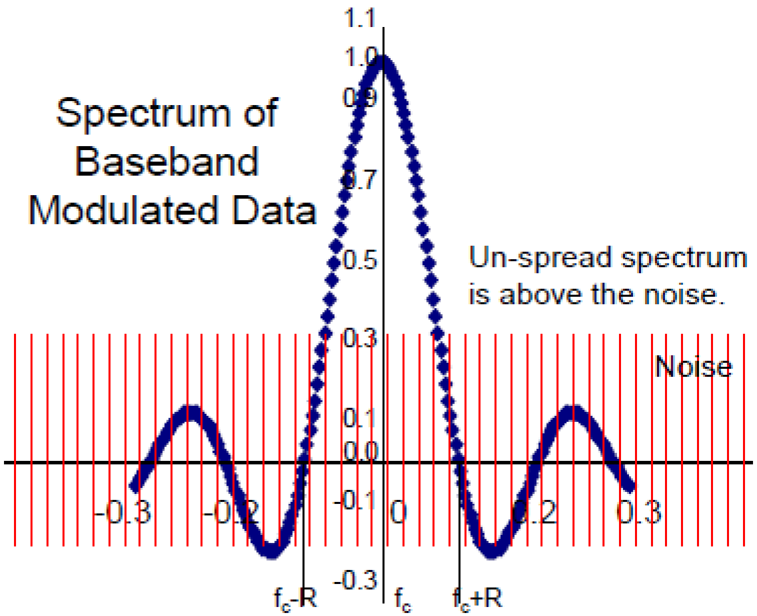
Current Accuracy Requirement
Determine beacon location within 5km, 95% of time within 10 minutes of beacon activation

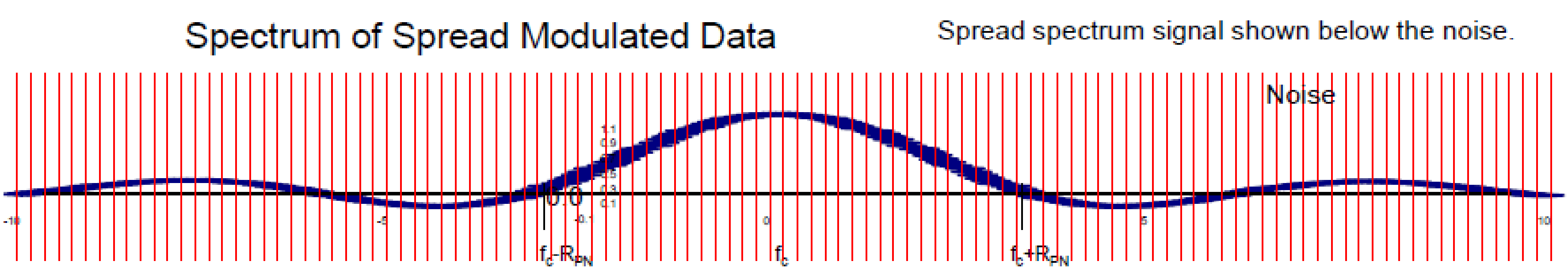
SGB Prob. Of Detection Requirement
99.9% probability of detection of at least one valid beacon message within 30 seconds after activation.

Spread Spectrum/Code Division Multiple Access

With the same PA output power, area under the Power spectrum curve is the same for spread and un-spread transmission.   Since Null to Null spacing is a function of the data rate, for spread data the spectrum is much wider, at least 10 times as wide for this specification.
Amplitude of power spectrum of spread signal is thus less than 1/10th the level of un-spread spectrum and will often be below the noise floor.

f_c = carrier center frequency
R = data rate of original data
R_{PN} = data rate of the PN chips





(Curves shown are linear Voltage spectrum and need to be squared for power spectrum)

6-Channel Software Defined Receiver

- Processes current and SGB signal relayed by GNSS satellites.
  - GPS
  - Galileo
  - GLONASS
  - Beidou
- Measurements made on each beacon burst fed into NASA MEOLUT for location processing.

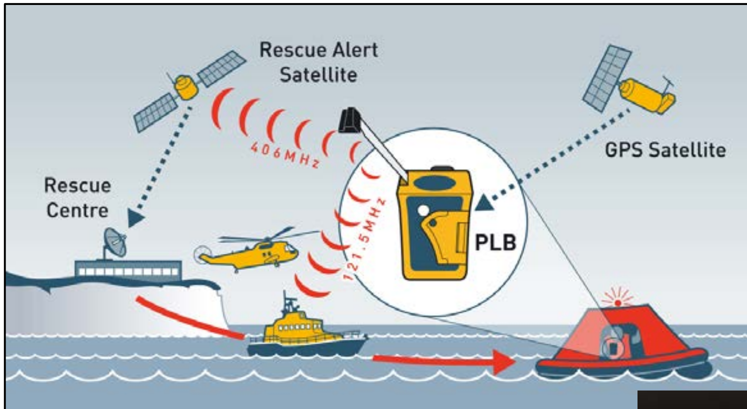
SGB Real Time Receiver

SGB Applications

Videos

ANGEL: World's first-approved SGB

ANGEL/Orion Crew Survival



- "Advanced Next Generation Emergency Locator"
- Develop SGB PLB for the NASA Orion crew survival
  - Attached to astronaut Life Preserver Unit (LPU)
  - For operation after splashdown and crew egress from capsule
  - Targeting Exploration Mission 2 (EM-2)
  - 406 MHz signal and 121.5 MHz swept-tone signal

NASA Collaboration on SGB

ANGEL/Orion Crew Survival Demo

- Since mid-2014, NASA Crew Survival Engineering and NASA Search & Rescue Mission Office have collaborated on the development of a miniaturized Second Generation Beacon (SGB) for use in the Orion Crew Survival System (OCCS)

- Blended team of GSFC and JSC engineering staff responsible for operational requirement development and prototype design representing eventual flight unit configuration for use in EM-2 rescue operations
  - GSFC responsible for electronics and mechanical design and coordination with international COSPAS/SARSAT community space & ground segments
  - JSC responsible for requirements development, 406 MHz antenna design, integration with MACES suit, and operational testing and interoperability with SAR forces. JSC will assume full programmatic responsibility for flight certification and flight operations.

UAS SAR & SGB DF Receiver

- Working with Rockwell Collins to develop an SGB 406MHz Direction Finding (DF) receiver that meets the DF and homing requirements of the next generation SAR beacon signals. The DF receiver will operate in the 406MHz frequency band

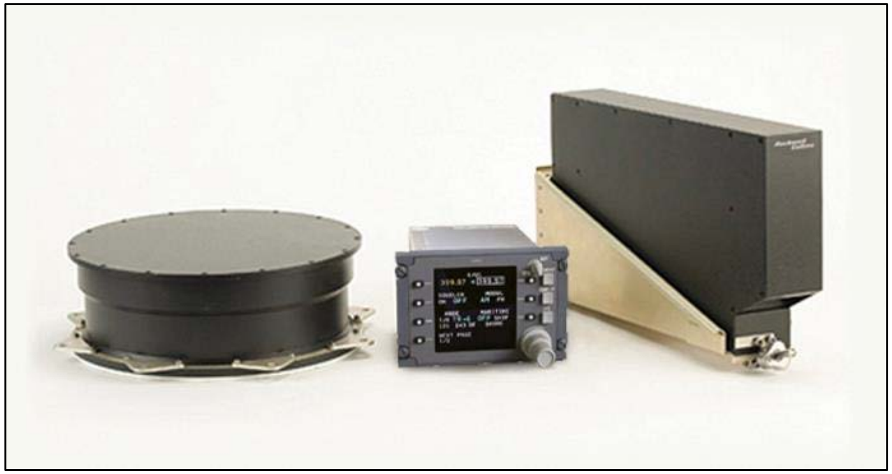
- SGB-DFR performance will be field tested on NASA's Sensor Integrated Environmental Remote Research Aircraft (SIERRA) Unmanned Aerial System (UAS)

- Partnering with University of Maryland UAS Test Site (Pax River) to for overall UAS SAR concept formulation for the Coast Guard

- The SG-DFR homing capability is scheduled to be field-tested in July 2019

UNITED STATES COAST GUARD 1790

UNIVERSITY OF MARYLAND 1856



Emergency Locator Transmitter (ELT) Survivability and Reliability

ELT Survivability & Reliability

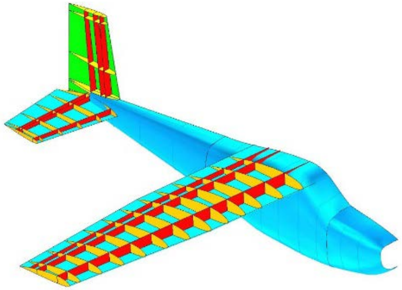
NASA SAR supporting RTCA/EUROCAE with the goal of making "*significant improvement to ELT performance*" through a multi-faceted research, test and analysis

Research:

- **Historic and current system performance**
  - Crash reports
  - Historic performance trends
  - Previous improvements
  - Failure mode identification

Analysis:

- **Nonlinear dynamics analysis of severe but survivable airplane crash scenarios**
  - Model validation by test correlation
  - Investigate various installation plans



Test:

- **Laboratory and full-scale experiments**
  - Crash Safety
  - Vibration
  - Fire/Flame
  - Full-scale Crash

Deliverables:

- **Recommendations to RTCA / EUROCAE regarding Minimum Operational Performance Standards (MOPS)**

Crash Test Approach

CRAWL	WALK	RUN

Crashworthiness test from a leading vendor report

TRACT 1 Helicopter Crash Test at LandIR from 2013

Full-scale GA Airplane Crash Testing at LandIR from 1970's

- Current **crash safety testing** failed to identify failure mode of ELTs ejecting from their mounting trays in survivable crashes
- NASA demonstrated an improved test with more realistic loading conditions that formed the basis for recommendations to ELT Standards

- ELT systems were installed onboard a CH-46E fuselage for **TRACT 2** testing at LandIR on 24-25 Sept 2014
- The goal was to gain experience installing ELT systems and evaluate current design and installation performance at a low risk level

- Building on the lessons learned from the research phase, laboratory testing and helicopter crash test, a series of GA airplane crashes were conducted with multiple ELT systems installed
- The objective was to demonstrate best practices for system design and installation while also providing valuable real-world crash performance data regarding ELTs

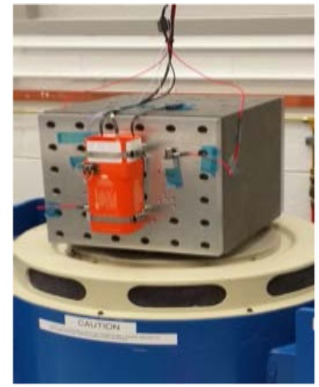
Laboratory Testing

Crash Safety & Functionality

Improved crash safety test parameters

Disconnected antenna due to beacon ejection

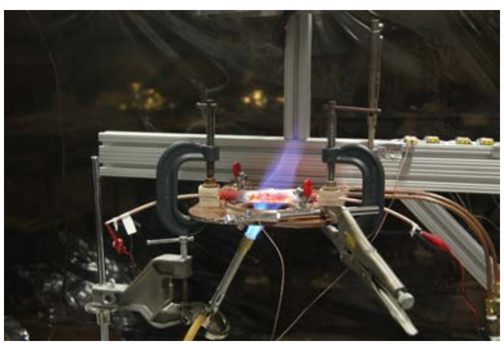
Vibration



Robust vibration testing

G-switch section view

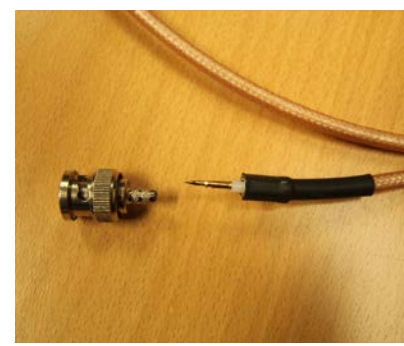
Fire/Flame Survivability



Antenna cable fire test with COTS insulation

Survivable crash with post-impact fire

Antenna Cable Strength



Typical cable system failure

Full-scale Crash Test & Analysis

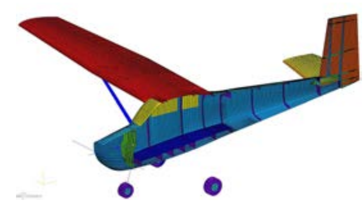
- Series of tests at NASA Langley Research Center's Landing and Impact Research Facility (LandIR)
  - 1 CH-46E Helicopter Fuselage (October 2014)
  - 3 Cessna 172 Airplanes (Summer 2015)

4 ELTs onboard: Cessna 172 Crash Test

LandIR

1977 C172 Crash Test

C172 test preparations



C172 analysis model (in development)

Enhanced installation guidance for the entire system under severe but survivable conditions

Updated Regulations

- In December 2018, the joint special committee on ELT test and installation guidelines concluded
  - Radio Technical Commission on Aeronautics (RTCA) Special Committee 229
  - European Organization for Civil Aviation Equipment (EUROCAE) Working Group 98

- Key Outcomes
  - Standards guiding the use of ELTs now incorporate all of NASA's recommendations for ELT installation and testing to maximize survivability and reliable operations
  - New release of 406 MHz ELT minimum operational performance standards
    - RTCA document DO-204B
    - EUROCAE document ED-62B
  - Resulting updates to FAA Technical Standards Order (TSO)-C126c (estimated April 2019)
    - Minimum performance standards U.S. ELTs must meet for certification
    - Affects all 406MHz ELT installations following a phase-in period (18 months from publication)
  - **ELT Installation Manuals** must adhere to DO-204B Section 6.2 (see backup slides for NASA study results that now reside in DO-204B).

"New models of 406 MHz ELTs identified and manufactured on or after the effective date of this TSO must meet the requirements in Sections 2, 3, and 4 of RTCA/DO-204B, *Minimum Operational Performance Standard for Aircraft Emergency Locator Transmitters 406 MHz*, dated 12/18/18."

Backup

ELTSAR Study Results*

Topic	Recommendation(s)
ELT Manufacturer Installation Instructions	1. Require inclusion of specific ELT System installation requirements within ELT Manufacturer-supplied documentation.
Vibration	1. Require vibration testing in accordance with robust levels defined in DO-160G § 8.2.1.2. 2. Require pre-and post-test verification of crash-sensor performance. 3. Perform vibration testing in the sequence of tests required to be performed with a single unit, before shock and crash safety.
Automatic Crash Activation	1. Require verification of performance in the “no activation” region for pulses of less than 10-msec duration. 2. Define crash activation sensor response curves with increased activation thresholds in directions other than normal flight. 3. If crash safety testing is updated to include multi-axis load conditions and automatic activation is required (as applicable), the “cross-axis inputs” test may be optional.
Crash Safety	1. Require demonstration of functionality (including automatic activation, as applicable) for all tests performed. 2. Require 6 additional test cases with the beacon oriented at ±45° with respect to each of the 3 primary directions. 3. Require an additional test case for each of the 3 primary beacon directions using a pulse of no less than 15-g and no less than 50-msec duration.
Flame Test	1. Require the duration of exposure to support system functionality, i.e., no less than the time between automatic activation and the first 406 MHz transmission. 2. Require demonstration of full system functionality after exposure to the environment, i.e. successful VSWR test of the antenna and coaxial cable (outfitted with a firesleeve, if necessary).
External Antenna Location	1. The antenna should be located at the same longitudinal location as the beacon. In the event this is not possible, a strain relief loop in accordance with FAA AC 43-13-1B requirements for minimum bend radius of coaxial cables should be required.
Coaxial Cable	1. Require application of fire resistant material in accodance with SAE AS1072. 2. Replace the requirement for “vibration-proof RF connectors” with “MIL-DTL-17 cables and connectors or equipment that is appropriate for the vibration profile at the installation location”. 3. In addition to the requirement to include “some slack” in the cable, require a strain relief loop of minimum bend radius 6 times the outer diameter of the cable whenever the beacon and antenna are not located at the same longitudinal station in the aircraft. 4. In addition to the requirement for the cable to “be secured to the aircraft structures for support and protection.”, require that such support be provided at intervals of not more than 24”. 5. Provide additional clarification to the definition of “aircraft production breaks”.

*Results of NASA research have been successfully incorporated into DO-204B and ED-62B.

Future Concepts

SIGNaL: SAR Integrated Generation Nano Locator

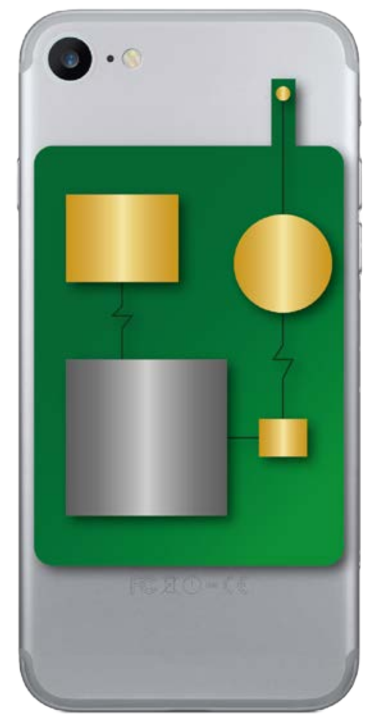
Option 1 – Smartphone C-S Beacon

Smartphone Front

- Downloadable Cospas-SARSat App:
  - If in cellular-starved area (no 911), trigger transmission
  - If RLS-equipped – receive message of acknowledgement from SAR forces

Smartphone Back

- External bump approximately ¼" thick consisting of:
  - Electronic boards
  - Rechargeable lithium ion battery
  - Antenna
  - Utilizes GPS chip already in smartphone

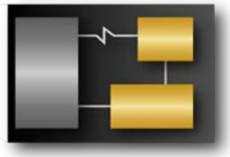


Future Concepts

SIGNaL: SAR Integrated Generation Nano Locator

Option 2 – PLB Embedded in Clothing

- 6”X6” patch antenna, integrated into the fabric of the jacket
- Push button activation
- Removable, rechargeable battery pack
- PLB
  - 406MHz with GPS chip



Future Concepts

Local Homer

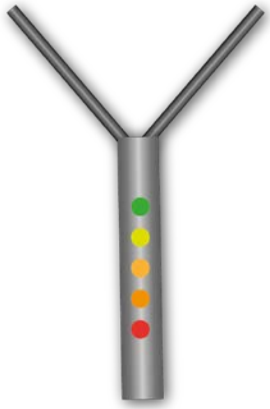
Vehicle edition

406Mhz SGB receiver and external antenna

- Antenna secured to vehicle roof
  - ~1-foot in diameter
  - Wired from antenna to receiver
- Receiver equipment stored in trunk of vehicle

Local Homer

Handheld



Handheld 406 MHz SGB homing device

- ~10-inches in diameter
- Lights on device indicate direction and distance to person in distress to assist rescue personnel