National Aeronautics and Space Administration

NASA Search and Rescue Beacon Manufacturer's Workshop

September 20, 2019

David Watson
Systems Engineer
NASA Search and Rescue Office
Goddard Space Flight Center

AGENDA

- NASA's Role in SAR
- SGB Testing Status
  - C/S Program Level
  - EPG Status
  - ANGEL Beacon Testing
- Space Segment:
  - SAR/GPS Status
  - RLS Highlights
- ELT Survivability
- 406 MHz Homing

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

SGB Testing Status

SGB Status

- Proof of Concept and D&E phases are complete
- A commercially available PLB (ANGEL) was developed
- Working on type approval
- The build out of SGB compatible ground system capabilities is underway

Type Approval Status

- C/S established a technical panel, "*in coordination with the Secretariat to conduct the type approval reviews for SGBs and ELT(DT)s concurrently with the review of test facility applications for extended capabilities….*"
- The technical panel has established a review methodology for the test facilities' applications to extend their capabilities.
  - Focused on T.018 and T.021 traceability and coverage within the test procedures.
  - EPG's application is currently in review.
- ANGEL is anticipated to be the initial SGB submitted for type approval.

EPG Status

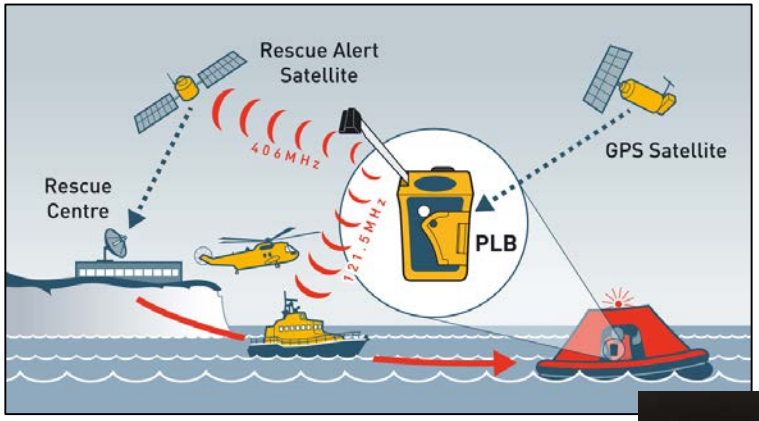
- EPG submitted the application to extend their test facility capabilities for SGB and SGB ELT(DT)s at the end of May 2019
- Utilizing semi-automated testing and data gathering
- Progressing through the experts panel review
- EIRP Testing:
  - Computer controlled gantry arm is installed and tested
  - Adjustable height turntable with ground planes
  - Supports Linear and RHCP
  - Comparison tested against the FGB test setup
  - Ready for formal testing with ANGEL

International Test Facilities

- Most indicate that they intend to submit applications to extend their capabilities within the next several months
- Will follow the same experts panel review process as EPG
- There is interest in the availability of SGB test beacons to support lab test procedure development and possible cross-check testing between labs.

ANGEL: World's Most Tested 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
  - 406 MHz signal and 121.5 MHz swept-tone signal

Videos

Shreveport Wave Pool

SAR/GPS Status

SAR/GPS

- Contracts were awarded in 2019:
  - USAF to LM for 22 GPS IIIF SVs
  - Canadian DND to MDA for the SAR repeater payload
- NASA is providing engineering expertise for mission assurance
- Design and engineering is underway
  - MDA SRR held August 2019
  - GPS IIIF HPE CDR scheduled for October 2019
- Launches are planned to start in 2026, replacing the existing DASS constellation

Emergency Locator Transmitter (ELT)

Survivability and Reliability

ELT Survivability & Reliability

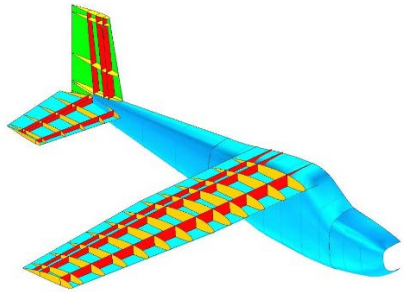
NASA SAR supporting RTCA/EUROCAE with the goal of making "*significant improvement to ELT performance*" through a multi-faceted research, test and analysis

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)**

RTCA
THE GOLD STANDARD FOR AVIATION SINCE 1935

EUROCAE

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

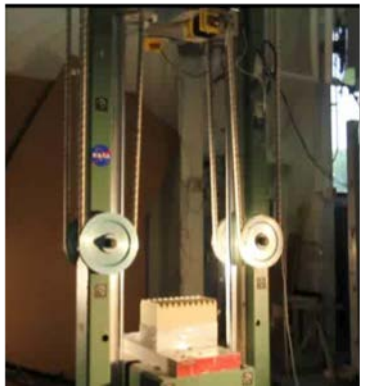
- Current **crash safety testing** failed to identify failure mode of ELTs ejecting from their mounting trays in survivable crashes
- NASA demonstrated an improved test with more realistic loading conditions that formed the basis for recommendations to ELT Standards

- 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

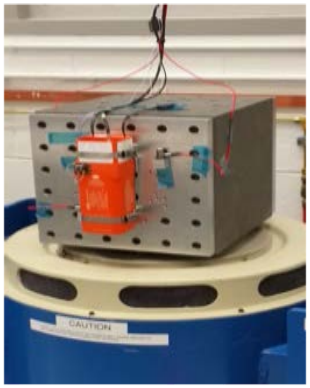
Crash Safety & Functionality



Improved crash safety test parameters

Disconnected antenna due to beacon ejection

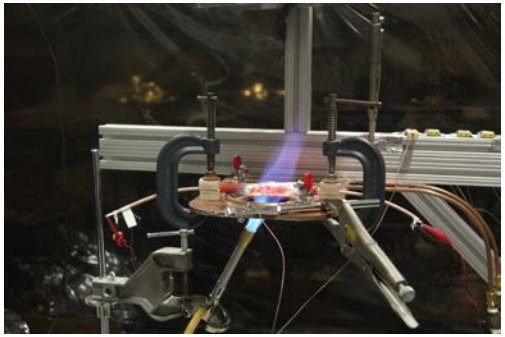
Vibration



Robust vibration testing

G-switch section view

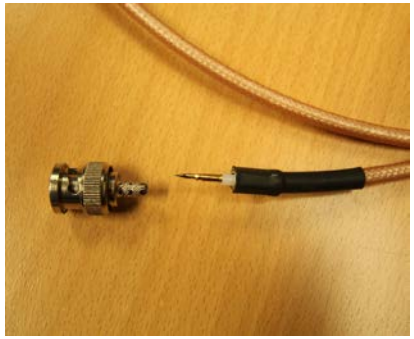
Fire/Flame Survivability



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

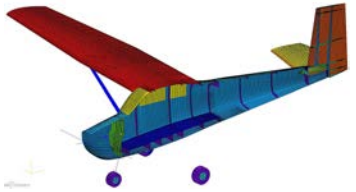
- Series of tests at NASA Langley Research Center's Landing and Impact Research Facility (LandIR)
  - 1 CH-46E Helicopter Fuselage (October 2014)
  - 3 Cessna 172 Airplanes (Summer 2015)

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 (March 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

"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."

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.

RLS

RLS HIGHLIGHTS

- The EC has deployed and is testing a RLS capability using Galileo
- The Galileo RLS capability is going through the international C/S review process
  - Near monthly EWG meetings, simulations, analysis and tests
- The U.S. is meeting our international commitments for the ground segment to be able to receive and process RLS capable beacons
- There are no plans for a similar GPS return link capability
- China announced plans for a BDS RLS capability, using the B2b downlink at 1207.14 MHz.

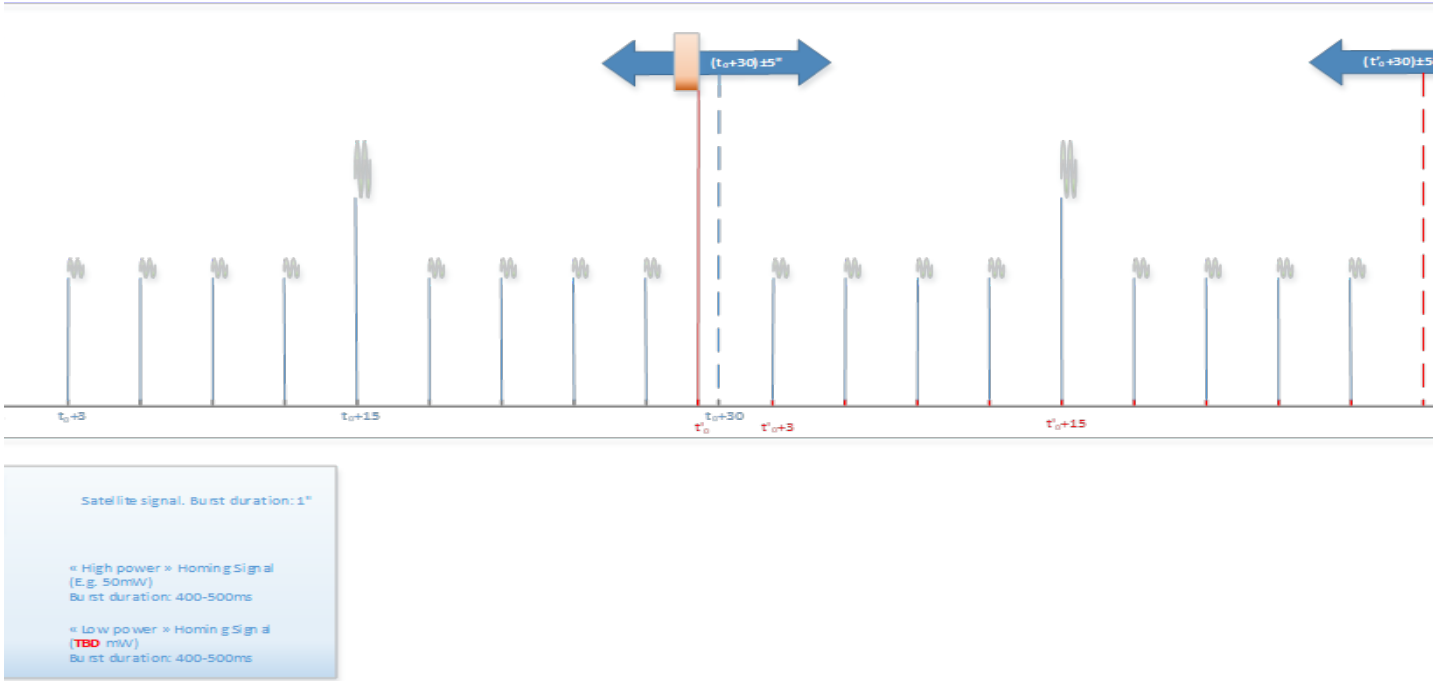
406 MHz Homing

SGB DF Background

- With current equipment, SAR forces will not be able to DF on the SGB spread spectrum satellite signal, like they do today with FGBs.
- Used by SAR forces to get within range for 121.5 MHz homing
- The current model used by the USCG is the Rockwell Collins DF-500. It can DF any signal that it can tune to and receive, including the FGB satellite signal
- NASA is working with Rockwell Collins to develop the DFR-500 to detect and DF on the SGB spread spectrum satellite signal, and the low power 406 homing signals.
- Current testing aims to identify appropriate beacon transmit power levels for 406 MHz local homing.

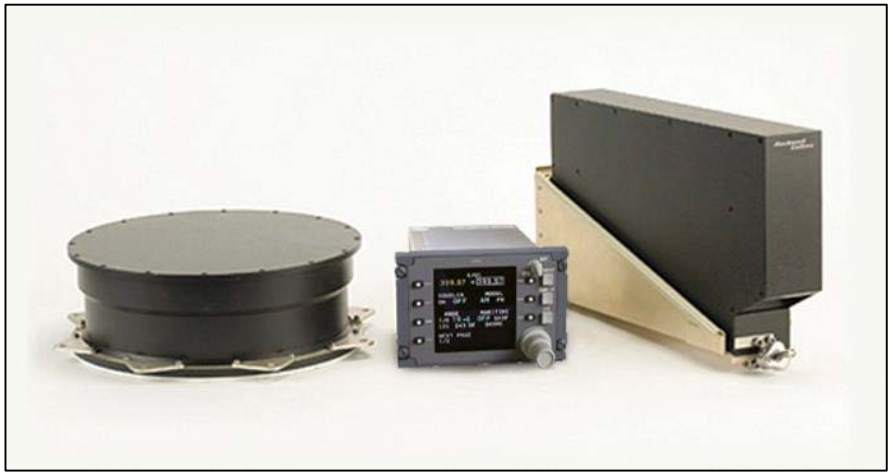
SGB DF Signals

- Three different 406 MHz SGB signals for the DFR to locate
  - (A) 5W Spread spectrum SGB to satellite message, which the DFR can detect and DF at greater than 100 nm
  - (B) 100 mW (nominal) High Power Continuous Wave (CW) homing signal, which repeats every 15 seconds, detectable at 30 nm
  - (C) 25 mW (nominal) Low Power CW homing signal, which repeats every 3 seconds, detectable at 8 nm



Flight Testing

- Provides an upgrade path for the DF-500 in use by the USCG
- Flight Tests Verified Beacon Power Levels and Detection Ranges
- Multiple Patterns: Inbound, Outbound, Circular
- Manned flight testing completed in the spring/summer of 2019



UAS SAR & SGB DF Receiver

- DFR-500 performance will be field tested on NASA's Sensor Integrated Environmental Remote Research Aircraft (SIERRA) Unmanned Aerial System (UAS)
- Evaluating Ops Concepts and suitability of UAS as SAR DF platform
- Payload integration and ground testing completed August 2019
- The DFR-500 homing capability is scheduled to be flight-tested in November 2019