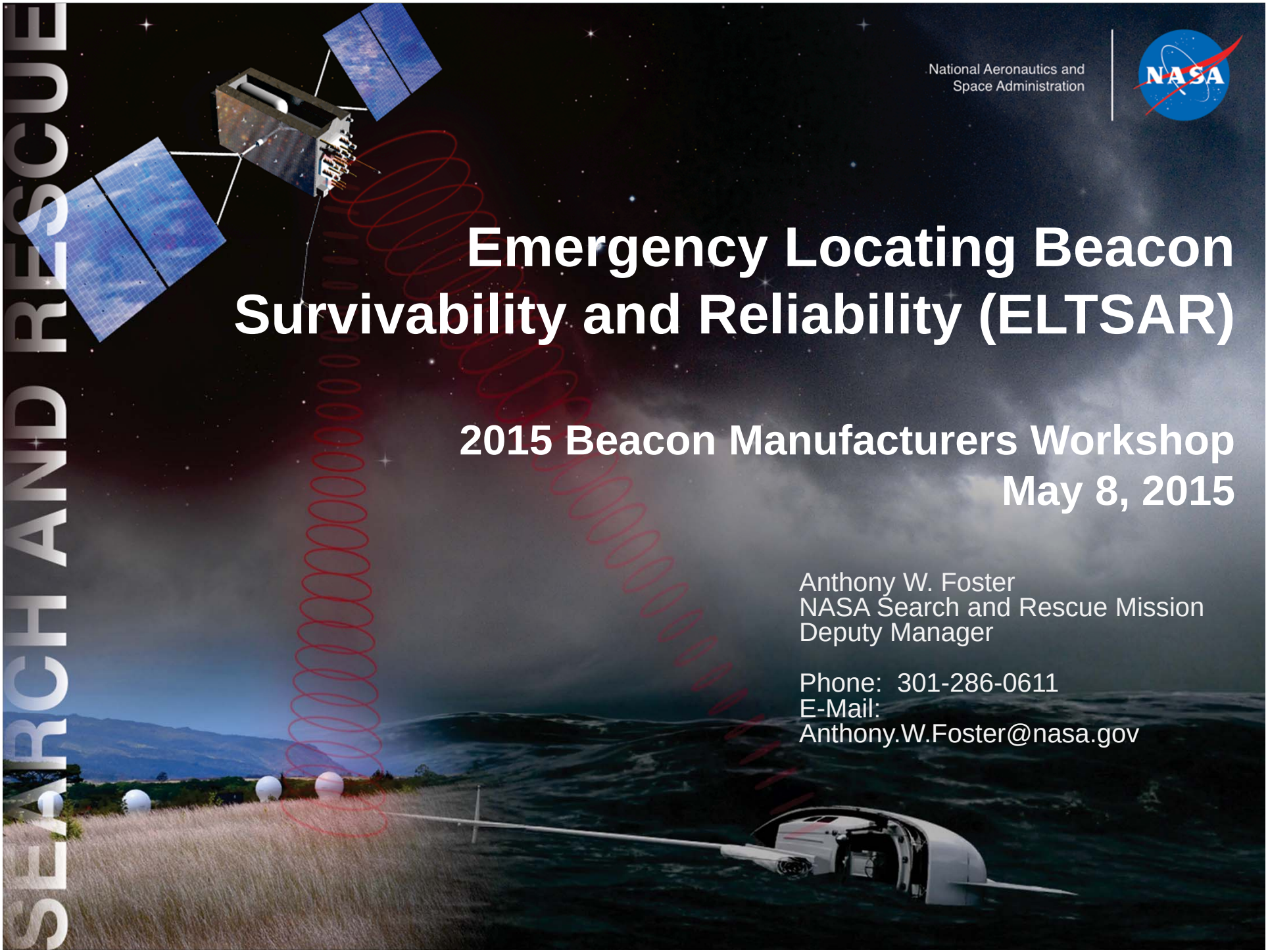

National Aeronautics and Space Administration

Emergency Locating Beacon Survivability and Reliability (ELTSAR)

2015 Beacon Manufacturers Workshop
May 8, 2015

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RTCA SC-229, WG-2 ToR

- WG-2 “Crash Safety & Reliability” will provide WG-5 a set of *empirically-based* recommendations for adoption in DO-204B that will result in improved performance of 2nd generation ELT systems. The scope of these recommendations will address known failure modes of 1st generation ELT systems related to crash safety, automatic activation (when applicable), fire/flame survivability, vibration sensitivity, and overall system installation.

NASA Project Overview

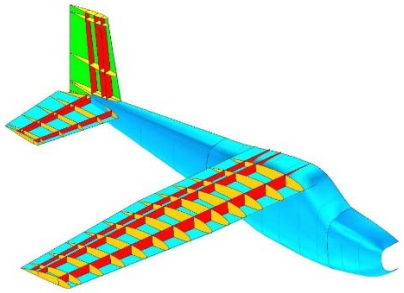
NASA SAR is supporting RTCA with the goal of making "*significant improvement to ELT performance*" through a multi-faceted research, test and analysis effort

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

Findings & Action Plan

- ELTs fail to meet performance expectations, in part, due to inadequate performance specifications in several areas:
  - Vibration
  - Fire/Flame Survivability
  - Automatic Activation
  - Crash Safety
  - System Installation

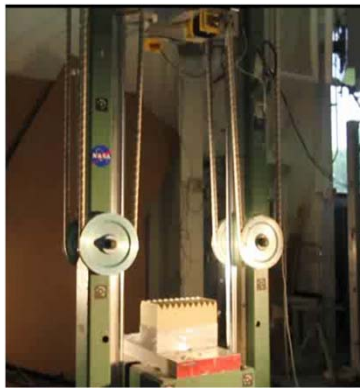
2010 crash in Alaska involving former U.S. Sen. Stevens and former NASA Admn. O'Keefe

Empirically-based performance specifications will be developed that address classic failure modes

SAR

Laboratory Testing

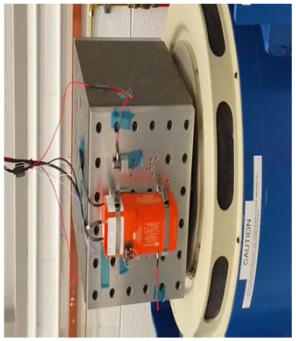
Crash Safety & Functionality



Improved crash safety test parameters

Disconnected antenna due to beacon ejection

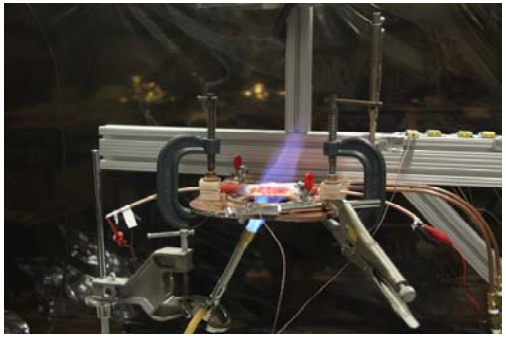
Vibration



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

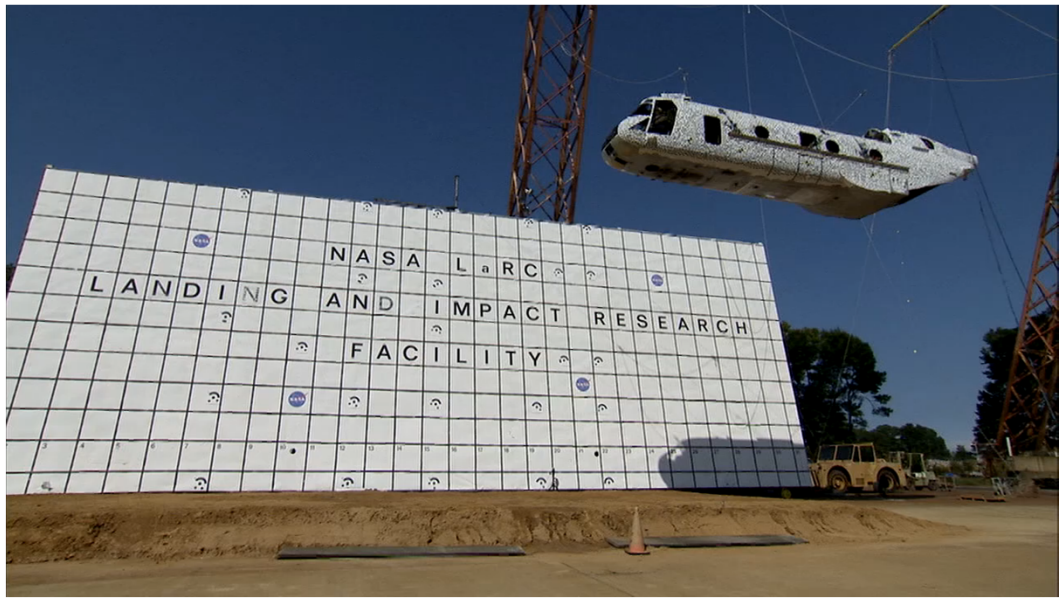
Typical cable system failure

Vibration Test Status

- Test plan includes robust test environments from DO-160G
- Conduct:
  - Variety of ELTs to be tested (1 & 6-axis mechanical g-switches)
  - Perform self- and g-switch tests before, during and after
  - G-switch test
    - Aligned with longitudinal sensing axis
    - Pulse below and above DO-204A activation threshold
- Objectives:
  - Assess the ability of current systems to withstand robust vibration testing and remain within performance specification for automatic activation
  - Install successfully tested ELTs with in-spec g-switches onboard crash tests
  - Apply lessons learned to DO-204B vibration specifications

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)

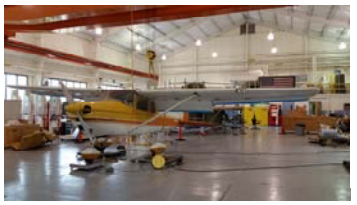


4 ELTs onboard Helicopter Crash Test

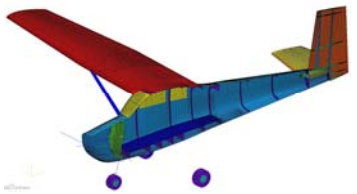
Enhanced installation guidance for the entire system under severe but survivable conditions

LandIR

1977 C172 Crash Test



C172 test preparations



C172 analysis model (in development)

GA Plane Crash Test Series

- Full-field photogrammetry, high-speed video (external and onboard) & 64 onboard data channels recording:
  - Airframe & ELT acceleration, pilot & co-pilot loads, antenna cable loads
- 4 live ELTs per plane (12 total)
- Installation Options:
  - Beacon Location: Cabin or Tail
  - Beacon Orientation: Floor, Side, Ceiling, Ceiling 45°
  - Antenna Location: Cabin or Tail
  - Antenna Proximity to Beacon: Same frame or other frame

#	Date (tentative)	Velocity	Pitch	Surface
1	01 Jul 2015	72 fps	+8°	Concrete
2	29 Jul 2015	80 fps	0°	Soil
3	26 Aug 2015	80 fps	-15°	Soil

Summary

- Ongoing collaboration with NTSB to enhance ELT data collection in crash reports
- Recommendations being made to RTCA & EUROCAE that will result in significant performance improvements

Thank-you for listening.
Questions?

Backup

ELTSAR High-Level Schedule

Phase	Activities	Status	ECD
1	Research & Planning		
	Literature Review	Complete	-
	NTSB Special Study	Complete	-
	Develop Project Plan	Complete	-
2	Laboratory Testing		
	Crash Safety (Vertical Drop Tower)	Complete	-
	Vibration	In-work	FY15 Q3
3	Helicopter Crash Test (TRACT 2)	Complete	-
4	GA Airplane Crash Testing	In-work	FY15 Q4
5	Analysis, Documentation & Closeout		
	Crash Analysis	In-work	FY16 Q2
	Final Recommendations to RTCA SC-229	In-work	FY16 Q2

Research Summary

- Historical Performance [1]
  - Success rate estimated to be 25% with TSO C-91 and earlier beacons
- Contemporary Studies by International Partners [2]-[6]
  - Success rate hovers around 50% with significant data uncertainty
- Current NASA/NTSB Special Study [7]
  - 58% success rate in TSO-C91a and later ELTs involved in injurious accidents over the period Jan 2009-Mar 2014
- Enhanced Data Collection
  - NTSB Form 6120.1 has been updated to include additional fields for ELT information

ELT failure is responsible for the loss of more than 1 life per week on average [1]

List of references included in backup

WG-2 Meeting History

Meeting	Date	Activity
Plenary #1 Washington	**Mar 2014**	**SC-229 ToR and WG formulation**
WG-2 Telecom	Apr 2014	
WG-2 Telecom	May 2014	
WG-2 Telecom	Jun 2014	
WG-2 Telecom	Jul 2014	
WG-2 Telecom	Aug 2014	
Plenary #2 Toulouse	**Sep 2014**	**Preliminary test results and plan forward**
WG-2 Telecom	Oct 2014	Helicopter crash test complete
WG-2 Telecom	Nov 2014	
WG-2 Telecom	Dec 2014	
Plenary #3 Washington	**Jan 2015**	**Status, research findings, preliminary test results, scope of DO-204B recommendations**
WG-2 Telecom	Feb 2015	

WG-2 Forward Planning
Objectives for 2015 Meetings

Meeting	Date	Activity
WG-2 Telecom	Mar 2015	Crash safety testing complete
Plenary #4 Hamburg	**Apr 2015**	**Draft crash safety & fire recommendations**
WG-2 Telecom	May 2015	
WG-2 Telecom	Jun 2015	Vibration testing complete
WG-2 NASA LaRC	**Jul 2015**	**Meeting at NASA in parallel with crash test #2**
WG-2 Telecom	Aug 2015	Airplane crash testing complete
Plenary #5 Washington	**Sep 2015**	**(1) Deliver final crash safety & fire recommendations to WG-5** **(2) Draft vibration recommendations**
WG-2/-5 Telecom	Oct 2015	
WG-2/-5 Telecom	Nov 2015	Airplane crash analysis complete
Plenary #6 Paris	**Dec 2015**	**(1) Deliver final vibration recommendations to WG-5** **(2) Draft system installation & automatic activation recommendations**

WG-2 Forward Planning
Objectives for 2016 Meetings

Meeting	Date	Activity
WG-2/-5 Telecom	Jan 2016	
WG-2/-5 Telecom	Feb 2016	
WG-2/-5 Telecom	Mar 2016	
Plenary #7 Washington	**Apr 2016**	**Deliver final system installation and automatic activation recommendations to WG-5**
WG-2/-5 Telecom	May 2016	
WG-2/-5 Telecom	Jun 2016	
WG-2/-5 Telecom	Jul 2016	
Plenary #8 Europe	**Aug 2016**	**WG-5 delivers DO-204B to SC-229 to begin FRAC process**
WG-5 Telecom	Sep 2016	
WG-5 Telecom	Oct 2016	
WG-5 Telecom	Nov 2016	
Plenary #9 Washington	**Dec 2016**	**FRAC process**

DO-204A Recommendations
§2.6.3.2 Crash Safety

2.6.3.2 Crash Safety (§2.2.5)

The equipment **shall** be secured, in the non-operating mode, to the shock tester, utilizing its normal aircraft installation configuration.

Adjust the shock tester to deliver a shock pulse having a half-sine wave with a duration of 23.0 ±2.0 milliseconds and an amplitude as specified below for each test direction. The instrumentation to demonstrate compliance **shall** have a 3 dB response over the range of at least 5 to 250 Hz. With the equipment mounted in its normal aircraft configuration, apply one shock in each of the following directions:

b. Upward - 100 G

c. Downward - 100 G

d. Backward - 100 G

e. Forward - 100 G

f. Sideward - 100 G (2 directions)

Upon completion of this test, the ELT shall be turned ON. The ELT must meet the aliveness test of Subsection 2.3.

1. Include multiple pulses to represent bounds of environment

2. Include multi-axis orientations, which failed previously qualified designs in ELTSAR testing

3. Demonstrate automatic activation & transmission *during* the event

SAR

DO-204A Recommendations §2.3.7 Fire/Flame Test

2.3.7 Flame/Fire Test

The ELT Unit **shall** be activated in accordance with §2.3.1.1.c. (3) or manually switched ON if a crash acceleration sensor is not used. The ELT, antenna and antenna cabling **shall** be subjected to the following tests:

2.3.7.1 Flame Test (All ELTs)

At the start of the flame test the temperature of the ELT **shall** have been allowed to stabilize in an ambient temperature of +25° C.

a. The fire source **shall** be a tray, 1 m (3.28 ft) square and 100 mm (4 in) deep, containing water to a depth of five cm, (2 in) on which is floated 10 liters (2.64 U.S. gallons) of Avgas (100 LL). The Avgas is ignited and allowed to burn for 15 ±2 s, before carrying out the following flame test.

b. The equipment under test **shall** be placed in a position directly over the center of the fire tray at a height of 1 ±0.025 m (39 in ±1 in), above the tray.

c. The equipment under test **shall** remain in the flame for a minimum period of 15 seconds.

d. The test **shall** be conducted in still air if possible.

e. After removal from the flame, the equipment under test **shall** be allowed to cool naturally to ambient temperature before being tested. The ELT must meet the aliveness test of Subsection 2.3.

f. Ensure that all mechanical devices operate satisfactorily.

2.3.7.2 Fire Test (When Required)

The ELT(AF) **shall** be subjected to a fire of at least 1,100° C, producing a thermal flux of 20 W/cm^2 (63,400 BTU/ft^2 hr) minimum. The minimum diameter of the area of the fire **shall** be twice the maximum diagonal dimension of the ELT. The flames **shall** envelop the outside area of the ELT under test for a continuous and uninterrupted period *of at least* two minutes.

After removal from the flame, the equipment under test **shall** be allowed to cool naturally to ambient temperature before being tested. The ELT must meet the aliveness test of Subsection 2.3.

Note, per Table 2-2, the fire test is optional for AF & AP and Not Applicable for S & AD type ELTs

1. Duration should be performance-based, i.e. a desired multiple of satellite bursts

2. Confirm functionality *during* event, perhaps via remote activation and monitoring

3. Merge the fire/flame tests into a single, performance-based test that considers operational characteristics, such as satellite transmission delay times and functionality *during* event

List of References

1) NASA CR-4330, “Current ELT Deficiencies and Potential Improvements Utilizing TSO-C91a ELTs”, Trudell, B. and Dreibelbis, R., dated 1990.
2) ATSB Report AR-2012-12B, “A Review of the Effectiveness of Emergency Locator Transmitters in Aviation Accidents”, dated 21 May 2013.
3) Defence R&D Canada Report TR 2009-101, “ELT Performance in Canada from 2003 to 2008”, Keillor, J. et al, dated September 2009.
4) German BFU Presentation to the Cospas-Sarsat Experts Working Group, “Reliability of 406 MHz ELT in Aircraft”, Lampert, P., dated January 2011.
5) Cospas-Sarsat Council 45th Session Open Meeting Agenda Item 8.2, “Continuous Monitoring of the Performance of Beacons Through Integrated Safety Analysis”, ICAO, dated 7 September 2010.
6) New Zealand CAA Report, “Missing Aircraft Detection & Location, Technology and System Status Review 2010”, Doggett, R., dated 8 January 2010.
7) NASA Presentation to RTCA SC-229 WG-2 at Plenary #2, “ELTSAR Phase 1: Research & Work Plan”, Stimson, C., dated 3-5 September 2014.