



Federal Aviation Administration

Memorandum

Date: December 10, 2015

To: Manager, Ft. Worth Aircraft Certification Office, ASW-130

From: Manager, Small Airplane Directorate, ACE-100

Prepared by: Trong Pham, Ft. Worth Aircraft Certification Office, ASW-130

Subject: INFORMATION: Equivalent Level of Safety (ELOS) Finding for BHE & Associates, Ltd., for the Textron-Beechcraft King Air Models B300 and B300C Powerplant Engine Instrument Display, FAA Project # ST1933DRB-A

ELOS Memo#: ST1933DRB-A-F-1

Regulatory Ref: 14 CFR 23.1305(a)(2), (a)(3), (c)(2), and (c)(5), amendment 23-52
14 CFR 23.1311(a)(6) and (a)(7), amendment 23-62
14 CFR 23.1549(a), (b), and (c), amendment 23-45

This memorandum informs the certificate management aircraft certification office of an evaluation made by the Small Airplane Directorate (SAD) on the establishment of an equivalent level of safety (ELOS) finding for installing Rockwell Collins, Inc. Pro Line Fusion® Integrated Avionics System (powerplant engine instrument digital display) on the Textron-Beechcraft, King Air Models B300 and B300C airplanes. The basis of this ELOS finding is the project specific memorandum for BHE & Associates, Ltd, Beechcraft models B300 and B300C, Project Number ST1933DRB-A, 14 CFR Part 23 Aircraft Powerplant Instruments (Displays), issued August 25, 2015, designated as issue paper (IP) F-1 for this ELOS finding.

Background:

This ELOS finding pertains to the usage of a digital only display and alternate markings for the ProLine Fusion® Powerplant Engine Instrument Display, manufactured by Rockwell Collins, Inc., in certain Textron-Beechcraft King Air Model B300 and B300C airplanes. A digital only display of engine oil pressure, oil temperature, fuel flow, and high-pressure rotor speed rpm (N1) is included instead of full time analog display for each parameter. The digital display utilizes sensory cues that are alternative and in addition to those required by the applicable regulations below.

Digital Only Display

Advisory Circular (AC) 23.1311-1C, Installation of Electronic Display in Part 23 Airplanes,

paragraph 9.4c, provides the basis for establishing an equivalent level of safety for a digital only display of oil pressure, oil temperature, fuel flow, and engine high-pressure rotor speed (N1) rpm.

Sensory Cues

AC 23.1311-1C, paragraph 9.4, specifies that “Section 23.1311(a)(6), amendment 23-62, requires sensory cues that provide a quick glance sense of rate and, where appropriate, trend information to the parameter being displayed to the pilot.”

AC 23.1311-1C, paragraph 9.5, specifies that “Alternate markings that do not comply with the requirements of § 23.1549 require an ELOS.”

Applicable Regulations:

Digital Only Display

14 CFR 23.1305(a)(2), (a)(3), (c)(2), and (c)(5)

14 CFR 23.1549(a), (b), and (c)

Sensory Cues

14 CFR 23.1311(a)(6) and (a)(7)

14 CFR 23.1549(a), (b), and (c)

Regulations Requiring an ELOS Finding:

Digital Only Display:

Section 23.1305, amendment 23-52, in pertinent part, states:

“(a) For all airplanes.

(2) An oil pressure indicator for each engine.

(3) An oil temperature indicator for each engine.

(c) For turbine engine-powered airplanes. In addition to the powerplant instruments required by paragraph (a) of this section, the following powerplant instruments are required:

(2) A fuel flow meter indicator for each engine.

(5) A tachometer indicator (to indicate the speed of the rotors with established limiting speeds) for each engine.”

Section 23.1549, amendment 23-45, in pertinent part, states:

“(a) Each maximum and, if applicable, minimum safe operating limit must be marked with a red radial or a red line;”

(b) Each normal operating range must be marked with a green arc or green line, not extending beyond the maximum and minimum safe limits;”

(c) Each takeoff and precautionary range must be marked with a yellow arc or a yellow line; and...”

Sensory Cues:

Section 23.1311, amendment 23-62, in pertinent part, states:

“(a) Electronic display indicators, including those with features that make isolation and independence between powerplant instrument systems impractical, must:”

(6) “Incorporate sensory cues that provide a quick glance sense of rate and, where appropriate, trend information to the parameter being displayed to the pilot.”

(7) “Incorporate visual displays of instrument markings required by §§ 23.1541 through 23.1553, or visual displays that alert the pilot to abnormal operational values or approaches to established limitation values, for each parameter required to be displayed by this part.”

Section 23.1549, amendment 23-45, in pertinent part, states:

“(a) Each maximum and, if applicable, minimum safe operating limit must be marked with a red radial or a red line;”

(b) Each normal operating range must be marked with a green arc or green line, not extending beyond the maximum and minimum safe limits;”

(c) Each takeoff and precautionary range must be marked with a yellow arc or a yellow line ; and...”

Description of compensating design features or alternative Methods of Compliance (MoC) which allow the granting of the ELOS (including changes, limitations, or equipment needed for equivalency):

Digital Only Display:

The compensating features provided for the digital only display of engine oil pressure, oil temperature, fuel flow, and high-pressure rotor rpm (N1) are those identified in AC 23.1311-1C, paragraph 9.4c and are described below.

Digital only display of N1 Gas Generator Speed: The ProLine Fusion® Primary Engine Indication (figure 1) only displays digits to indicate N1 gas generator speed. Section 23.1305(c)(5) requires an indicator to present rotor speed. Section 23.1549(a)(b)(c), amendment 23-45, requires green, yellow, and red markings on the instruments to denote the normal, cautionary, and danger regions of operation. The maximum and minimum values cannot be marked with the required radial or line on a digital-only indicator. The compensating features of this indicator are that—

(1) The digits are displayed in color when a caution (yellow) or warning (red) value is reached, clearly indicating when the operating value is at or exceeding the maximum or minimum limit;

(2) The digits will be green in the normal operating range, a redundant N1 overspeed protection system is provided mitigating need for flightcrew action to prevent exceeding part 33 limits as described below; and

(3) The ProLine Fusion® Engine Synoptic page is available at any time, showing N1 as two left and right engine analog dials.

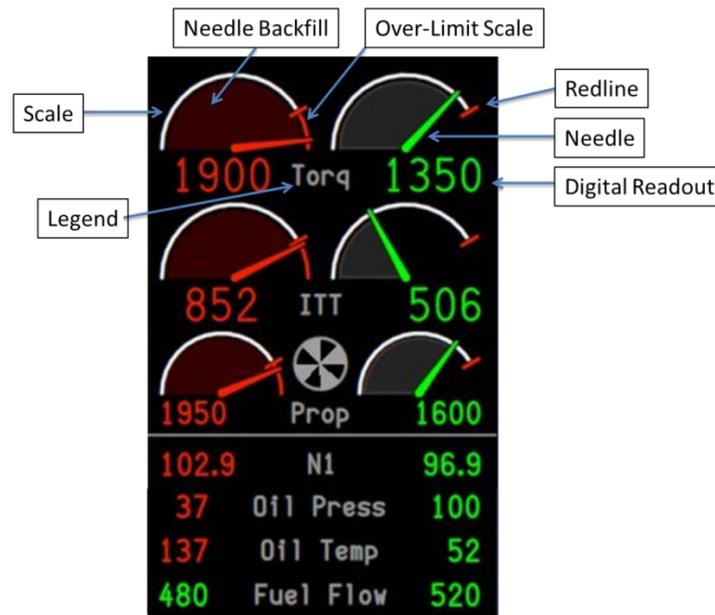


Figure 1—Primary Engine Indication

The synoptic page N1 speed indicator will have a green arc for the low range (e.g. 0 to 62%) during the “start” mode. The N1 minimum idle speed (e.g. 62%) is an adjustable mechanical stop on the engine. If the speed drops below the defined percentage (e.g. 62%) while in the “run” mode, the needle and digits turn amber in this speed range. In the normal operating range (e.g., 62% to 104%), the needle is green and digits will be green. If the engine N1 speed equals or exceeds the maximum limit (e.g., 104%) the arc, needle, and digits will turn red. These markings are color coded consistent with the intent of § 23.1549(a), (b), and (c), amendment 23-45, and AC 20-88A, Guidelines on the Marking of Aircraft, to indicate the normal, cautionary, and warning regions.

Digital only displays may be hard to determine whether the indicated value is increasing or decreasing because the numbers may be changing too fast. FAA policy states that digital N1 gas turbine speed indicators are only acceptable if there is an automatic system to prevent the engine’s gas turbine speed from exceeding its safe limits. The PT6A-60A turboprop engine used on the model B300/B300C series airplanes has an automatic N1 overspeed protection device certified as part of the engine. Textron Beechcraft refers to “Ng (Gas Generator) speed” as “N1 speed” in the King Air model B300/B300C airplanes, whereas Pratt & Whitney Canada (P&WC) uses the notation ‘Ng’. The Ng speed control system is described in the “P & WC PT6A-60/-65 Series Gas Turbine Engines Descriptive Notes”. P & WC’s Ng Overspeed Protection System’ description is as follows:

“The engine’s speed is controlled by the Ng speed sensor, which is a tachometer. The tachometer contains two mechanical flyweights mounted on a ballhead driven by the engine (gas generator). The flyweight is mechanically connected to a fuel flow valve, which controls the fuel flow to the engine. The centrifugal force generated by the flyweights is directly proportional to the Ng speed. There is a mechanical “stop” which prevents the fuel flow from allowing the gas generator Ng to overspeed beyond the limit (e.g.,104%), plus a small tolerance. Therefore, the maximum Ng speed is automatically limited by a highly reliable flyweight-to-fuel flow mechanical control mechanism, and the pilot does not need to control the maximum Ng speed.”

Digital only display of oil temperature and oil pressure: The ProLine Fusion® Primary Engine Indication (figure 1) only displays digits to indicate the oil temperature and pressure. Section 23.1549(a), (b), and (c), amendment 23-45, requires green, yellow, and red markings on the instruments to denote the normal, cautionary, and danger regions of operation. The maximum and minimum values cannot be marked with the required radial or line on a digital-only indicator. The ProLine Fusion® Engine Synoptic page shows the oil temperature and pressure indicators as two vertical bars with digits on either side indicating the left and right engine values. The bars are color coded consistent with guidance to indicate the normal, cautionary, and warning regions.

The compensating features of this indicator are that oil temperature and pressure are not controlled by the flight crew. Oil temperature changes do not typically occur so rapidly that required flightcrew action is necessary to prevent a limit exceedance. Oil pressure can rapidly change, but low oil pressure is the only region requiring flight crew action. When a low oil pressure condition occurs, a red CAS message, with accompanying master chime and aural tone, is displayed to the crew to increase awareness.

These two instruments also provide a compensating feature by displaying the digits in color when reaching a caution (yellow) or warning (red) value, clearly indicating when the operating value is at, or exceeding the maximum or minimum limit. The digits will be green in the normal operating range.

Digital only display of fuel flow: The ProLine Fusion® Primary Engine indication (figure 1) has digits only to indicate fuel flow, and these digits will always be green. Section 23.1305(c)(2) requires an indicator. Section 23.1549(a)(b)(c), amendment 23-45, requires green, yellow, and red markings on the instruments to denote the normal, cautionary, and warning regions of operation. However, there are no maximum and minimum values to be marked on this indicator. Therefore, the digits are always green in color. In addition, a ProLine Fusion® Engine Synoptic is available at any time to the flightcrew showing fuel flow indications in an analog format as a vertical bar, with green digits on either side indicating the left and right engine values. The compensating feature of this indicator is that there are no limits for fuel flow. With no limits, there is no need to assess rate of change or exceedance.

Sensory Cues:

Sensory cues that are alternative to the regulatory required sensory cues include aural annunciators, left to right comparators, flashing display features, and a propeller synchronization indicator. The compensating feature of these cues is that they provide a quick sense of rate change or trend information.

ProLine Fusion® Engine Indication System

The ProLine Fusion® engine indication philosophy can be generally described as showing the flightcrew normal indications under normal operating conditions with critical limits, and should a limit be approached, ProLine Fusion® will appropriately caution the impending limit. Color change and short duration flashing (5 seconds) is used to ensure immediate flightcrew attention, which was not practical on the original mechanical instruments. Additionally, the presentation has been improved with the replacement of ProLine 21 with ProLine Fusion®.

An improvement with ProLine Fusion® from ProLine 21 is that engine indication has been refined for simplified flightcrew use by separating each engine parameter to a separate gauge and consistently displaying the specific limiting red radial relative to the current operating conditions. When a warning limit is reached on a digital display, the digits flash red for five seconds to draw flightcrew attention. When a warning limit is reached on an analog gauge, a red arc is extended beyond the red radial and the needle and digits flash red for five seconds.

The ProLine Fusion® Engine Indication provides full time display of critical engine data, comprised of the following parameters in the engine indication crew alerting system (CAS) window:

- Torque
- Interstage turbine temperature (ITT)
- Prop
- N1
- Oil pressure
- Oil temperature
- Fuel flow
- Fire warning annunciation
- Prop sync
- Auto feather annunciation
- Ignition annunciation

The engine indication is displayed in a dedicated window typically on the center display. The parameters can also be viewed on the engine synoptic quarter format window.

The Primary engine indication parameters consist of torque, ITT, and prop RPM. They are displayed with a scale, red line, over-limit scale, needle, needle backfill, and digital readout as illustrated in figure 1. The secondary engine indication parameters are displayed with a digital readout and legend. The order of the secondary parameter is shown in the order of priority with N1 as the highest priority and fuel flow indication as the lowest priority as shown in figure 1.

This engine indication display does not strictly meet the definition of § 23.1549(a), (b), and (c), amendment 23-45, as colored arcs are not present full time.

Full time presentation of colored arcs was not present with the existing ProLine 21 engine indication display and is not on many other modern engine indication systems today. This would be inconsistent with the cockpit color standards, and flightcrew attention and working philosophies. The applicant believes that the many compensating features of ProLine Fusion® provides an ELOS to § 23.1549(a), (b), and (c), amendment 23-45. One of the compensating features is the availability of the engine indication synoptic display, which is an expanded engine

indication display. This engine indication synoptic display has a digital and analog instrument “Scale Face” for every instrument. The engine indication synoptic page complies with § 23.1549(a), (b), and (c), amendment 23-45. The engine indication synoptic page may be selected by the pilot at any time there is electrical power on the airplane’s systems.

Legends

Each engine indication parameter has a gray legend to uniquely identify the parameter with a descriptive label. Legends are used in lieu of units for all engine indication parameters in accordance with AC 25.11B, Electronic Flight Displays, which states:

“Data fields should be uniquely identified either with the unit of measurement or a descriptive label. However, some basic “T” instruments have been found to be acceptable without units of measurement.”

Below are the approved Technical Standard Order (TSO) deviations for the engine indication parameters not to display units:

- ITT TSO-C43c, Temperature Instruments
- Prop RPM TSO-C49b, Electric Tachometer
- N1 TSO-C49b, Electric Tachometer
- Oil Press TSO-C47a, Fuel, Oil, and Hydraulic Pressure Instruments
- Oil Temp TSO-C43c, Temperature Instruments

Fuel flow and torque indications do not have TSO requirements to display Units. Therefore, there are no TSO deviations.

Scale, Redline, and Over-Limit Scale

Each primary engine indication parameter has a fixed white scale to provide reference for the moving engine indication needle. The scale is colored white in accordance with AC 25.11B Chapter 5, Table 5-1 that recommends the color white for scales, dials, and tapes. This is consistent with the current implementation of the ProLine Fusion® engine indication. The original mechanical engine indication used on the King Air airplanes had variable red radial limits based on operation, and had no cautionary areas, with the exception of oil pressure.

ProLine 21 dramatically reduced flightcrew workload by removing the memorization, recognition, and timing efforts associated with engine indication, by introducing automatic cautions and warnings with timed triggers developed in conjunction with the airframe and engine manufactures. These timed triggers will not be changed with the transition from ProLine 21 to ProLine Fusion®. At the end of the scale is a red radial called the “Redline”. The Redline represents the divider line between normal operating range and cautionary/restricted operation. When the needle is to the left of the Redline, the engine parameter is within the normal operation range. When the needle is to the right of the Redline, the engine parameter is outside of the normal operating range and the Over-Limit Scale displays in red as shown in figure 2.

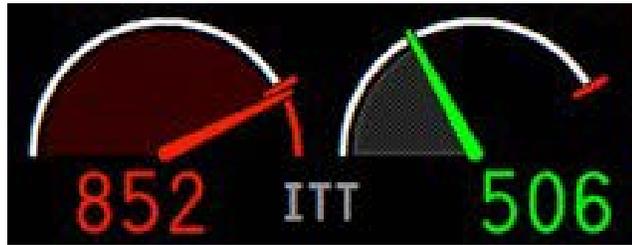


Figure 2—Redline and Over-Limit Scale

Needle, Backfill, Digital Readout

Each primary engine indication parameter displays a needle, which provides the flightcrew a visual reference of the engine parameters value in relation to the normal operating range and red line. The needle also provides dynamic trend information for when the engine parameter is increasing or decreasing.

Each needle is accompanied by the needle backfill that aids with providing clear contrast for the engine needle and trend. The backfill also provides a larger display area for caution and warning conditions to capture the flightcrew’s attention, as illustrated in figure 3. Each engine indication parameter provides a digital readout to indicate the clear digital value of the engine parameter.



Figure 3—Green-Yellow-Red Indications

The needle, needle backfill, and digital readout all provide quick status of the engine parameter by changing color dependent upon the normal, cautionary, or warning condition. The color green indicates the engine parameter is within normal operating range. The color yellow indicates the engine parameter is in the caution/transient range. The color red indicates the engine parameter is in the maximum/minimum range. The engine indication display does not strictly meet the definition of § 23.1549(a), (b), and (c), amendment 23-45, as described earlier, but offers justification for an ELOS that is consistent with the modern cockpit and offers a consistent use of color and operating philosophy.

The usage of green, yellow, and red in ProLine Fusion® engine indication meets complies with § 23.1322, amendment 23-43, Warning, caution, and advisory lights. Green indicates normal operation, yellow indicates operation in a takeoff or precautionary range, and red is used for warning lights. AC 23.1311-1C states:

“The use of color in accordance with § 23.1549 to indicate the state of operation: a green indication would indicate normal operation, a yellow indication would

indicate operation in a takeoff or precautionary range, and a red indication would indicate operation outside of the safe operating limits.”

GAMA Publication No. 10, Recommended Practices and Guidelines for Part 23 Cockpit/Flight Deck Design, says that green should be used to indicate monitored equipment that is within the normal tolerance. Yellow should be used to indicate marginal conditions or alert where caution is necessary. Red should be used to indicate hazardous conditions that require immediate pilot attention and may require pilot action.

Engine Indication & Smart Timers

The previously certified ProLine 21 system made some significant improvements in flightcrew engine indication “awareness” by—

- (1) Informing the flightcrew of impending warnings;
- (2) Introducing a cautionary range through accurate rates; and
- (3) Timing reflecting the engine manufacturers timing limits.

Mechanical gauges do not provide automatic monitoring. Warnings on these gauges are reached by crossing a red line or flightcrew memory based on determination of time spent at a certain value. The ProLine 21 advances in flightcrew interface with engine indication were noteworthy improvements, as most of the original instruments did not have a defined caution zone due to variable time limits, which the modern electronics of ProLine 21 avionics elegantly solved. These valuable engine indication improvements are further refined with the introduction of the ProLine Fusion®.

Attention Getting Cues

The engine indication system alerts the flightcrew to a change in status of the engine parameters using color changes, flashing (5 seconds) and an engine side specific aural alert. When an engine parameter changes from the normal range (green) to an abnormal state (yellow or red), the engine indication needle, backfill, and digital readout will flash once per second for five seconds to capture the attention of the flightcrew. Flashing also occurs when the engine indication transitions from a cautionary state (yellow) to a warning state (red). The Engine Indication System also provides an aural alert “attention getting cue” to direct flightcrew attention to the alert condition. A left engine alert will sound “Left Engine” when a left engine parameter changes to a warning state or in the event of a left engine fire. The right engine alert will sound “Right Engine” when a right engine parameter changes to a warning state or in the event of a right engine fire.

Additionally, the CAS sounds the Master Warning aural alert “triple chime” for CAS warning messages and sounds the Master Caution aural alert “single chime” for CAS caution messages. Referring to figure 4, for example, in the event the left engine oil pressure is low, the CAS would annunciate the “L Oil Press Low” warning CAS message in the CAS message list, and the left engine Oil Pressure indication would flash red for 5 seconds on the engine indication system. Additionally, the aural system would play a “triple chime” followed by “Left Engine” to alert the flightcrew to direct their attention to the left engine indication.

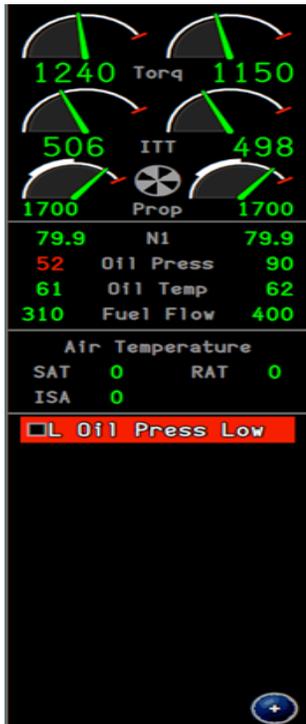


Figure 4 - Low Oil Pressure Visual Alert

Explanation of how design features or alternative Methods of Compliance (MoC) provide an equivalent level of safety intended by the regulation:

Digital Only Display:

AC 23.1311-1C, paragraph 9.4c, provides for compensating features for the digital only display of engine oil pressure, oil temperature, fuel flow, and high-pressure rotor rpm (N1). The explanation of how the design features for the digital only display of engine oil pressure, oil temperature, fuel flow, and high-pressure rotor rpm (N1) provide an ELOS are described below.

Digital only display of N1 Gas Generator Speed: The flightcrew indirectly controls N1 speed. The flightcrew uses propeller RPM and torque to set power. N1 speed will vary depending on ambient conditions, power extraction, engine condition etc. While N1 speed can change rapidly, trend information is not used to manage the engine. Limit exceedances are used to ensure safe engine operation at normal power settings. A mechanical flyweight governor and mechanical stop included in the engine design which prevents N1 overspeed without flightcrew intervention.

In addition, the ProLine Fusion® Engine Synoptic page is available at any time, showing N1 as two left and right engine analog dials marked in accordance with § 23.1549. Should the control system fail and N1 rotor speed exceed its allowable limits, then N1 digital indication, which changes color to warn the flight crew if any limits is exceeded, along with an aural indication provides an equivalent level of safety to the required indicator.

Digital only display of oil temperature and oil pressure: Oil temperature and pressure are not directly controlled by the flightcrew. A device within the oil system, independent of any flightcrew action, regulates the oil pressure. A thermostat within the oil system regulates oil temperature. Oil pressure and oil temperature do not typically change rapidly such that the

flightcrew would be required to act rapidly to prevent exceeding a limit. The oil pressure and temperature digital indications change color in accordance with § 23.1549, to warn the crew if any limit is exceeded. Variable limits based on engine operating condition are programmed into the system to reduce the need for multiple marking on a single indicator.

In addition, a ProLine Fusion® Engine Synoptic page is available at any time to the crew showing oil temperature and pressure indications in an analog format as two vertical bars with digits on each side indicating left and right values. The bars are color coded consistent with § 23.1549, amendment 23-45, to indicate normal, caution, and warning regions. These features provide an equivalent level of safety to the required indicators.

Digital only display of fuel flow: Engine fuel flow for the B300/B300C does not have fuel flow limits and is not used to indicate engine power or condition. As there are no fuel flow limits, there is no need to assess rapid rates of change to prevent an exceedance. The ProLine Fusion system fuel flow digits will always be green in accordance with § 23.1549. In addition, a ProLine Fusion® Engine Synoptic page is available at any time to the flightcrew showing fuel flow (FF) indications in an analog format as a vertical bar, with green digits on either side indicating the left and right engine values. Thus, with no reason to monitor fuel flow to assure proper engine operation, the digital fuel flow indicator provides an equivalent level of safety to the required fuel flow indicator.

Sensory Cues:

The sensory cue design features provide an ELOS because the instruments incorporate aural annunciations, left to right comparators, flashing display features, and a propeller synchronization indicator to assist in providing a quick sense of rate change or trend information.

FAA Approval Documentation of the ELOS Finding:

The FAA has approved the aforementioned equivalent level of safety finding using the Project Specific Policy Memorandum for BHE & Associates, Ltd., the Beechcraft Model B300 and B300C Airplanes, FAA Project #ST1933DRB-A, 14 CFR Part 23 Aircraft Powerplant Instruments (Displays) issued August 25, 2015 (IP F-1). This memorandum provides standardized documentation of the ELOS finding that is non-proprietary and can be made available to the public. The Accountable Directorate has assigned a unique ELOS Memorandum number (see front page) to facilitate archiving and retrieval of this ELOS. This ELOS memorandum number must be listed in the Type Certificate Data Sheet under the Certification Basis section (TCs and ATCs) or in the Limitations and Conditions section of the STC. An example of an appropriate statement is provided below.

Equivalent Level of Safety Findings has been made for the following regulations:

14 CFR 23.1305(a)(2), (a)(3), (c)(2), and (c)(5), amendment 23-52

14 CFR 23.1311(a)(6)(7), amendment 23-62

14 CFR 23.1549(a), (b), and (c), amendment 23-45

(documented in ELOS Memo ST1933DRB-A-F-1)

//SIGNED//

December 10, 2015

Mel Johnson, Acting Manager, Small Airplane Directorate
Aircraft Certification Service

Date

ELOS Originated by: Delegation Systems Certification Office	Manager, Delegation Systems Certification Office: Fran Cox	Routing Symbol: ASW-130
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