COLABMO TECHNICAL GUIDANCE

U.S. and European Display Systems Guidance

Airborne, ground and vehicle-mounted civil and military applications

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Technical guidance; not a substitute for the approved certification basis, regulatory pathway or contract.

Author: Diggy Breiling
General contact: info@colabmo.net | Author: diggybreiling@colabmo.net | www.colabmo.net | 941-416-1578

Purpose and use

This document provides a practical framework for identifying and flowing down electronic-display requirements for U.S. and European civil and military aircraft, rotorcraft, ground systems and vehicle-mounted systems. It focuses on cockpit instruments, multifunction displays, in-flight displays, NVIS-compatible equipment and ruggedized display assemblies.

The primary audience is the aircraft or vehicle system designer, display-system architect, certification engineer, optical engineer, quality organization and display supplier. It is intended to support requirements development, supplier selection, design reviews, qualification planning and compliance-matrix preparation.

Controlling principle
A compliant LCD, OLED, MicroLED engine, projector or TSO/ETSO article does not by itself make the installed system compliant. Certification and military airworthiness findings are made against the installed function, failure effects, human-machine interface, environmental exposure and approved configuration.

U.S. and EU regulatory basis. For normal-category airplanes, the early U.S. certification basis should identify 14 CFR §§ 23.2500 and 23.2510; the EASA counterparts are CS 23.2500 and CS 23.2510. For transport-category airplanes, 14 CFR §§ 25.1301 and 25.1309 and EASA CS 25.1301 and CS 25.1309 address intended function, installation, and equipment/system safety. Rotorcraft programs should identify the corresponding 14 CFR and EASA CS-27 or CS-29 paragraphs, including §§ 27.1301/27.1309 or §§ 29.1301/29.1309, as applicable. EASA certification projects should also identify the applicable Part-21 approval basis and means of compliance.

Normative language

Must. Identifies a binding regulatory, approval-basis or contractual obligation once applicable to the program.

Shall. Identifies an example supplier requirement that becomes mandatory only when incorporated into a specification or contract.

Should. Identifies recommended engineering practice that requires program-specific tailoring.

Applicability decision

Question	Why it matters
What platform and authority?	Selects FAA, EASA, national military authority, service airworthiness authority, road type-approval or ground-system rules.
What information is displayed?	Determines intended function, hazard classification, required integrity, alerting and crew reliance.
What installation environment?	Determines sunlight, NVIS, EMC, lightning/HIRF, vibration, temperature, contamination and power conditions.
What display acquisition model?	Determines the achievable control over design data, qualification evidence, configuration and obsolescence.
What approval path?	Determines whether evidence supports TSO/ETSO, TC/STC, military airworthiness, platform qualification or contract acceptance.

Contents

1. Regulatory and compliance architecture

The requirement stack should be established before optical or electrical requirements are frozen. A display specification is normally derived from four layers.

Layer	Content	Examples
1. Legal or airworthiness basis	Binding regulations, certification specifications, national military rules or vehicle type-approval requirements.	14 CFR Parts 23/25/27/29; EASA CS-23/25/27/29; national military airworthiness rules; FMVSS; EU vehicle regulations.
2. Accepted means of compliance	Authority-recognized guidance and standards used to demonstrate compliance.	FAA ACs; EASA AMC/GM; TSO/ETSO; DO-160/ED-14; DO-178C/ED-12C; DO-254/ED-80.
3. Program or contract requirements	Tailored military standards, platform environmental categories, mission needs and customer specifications.	MIL-HDBK-516D criteria; MIL-STD-3009; MIL-STD-810H; MIL-STD-461H; STANAG/AECTP; Def Stan.
4. Supplier product specification	Measurable requirements allocated to the display provider, including limits, test methods and deliverables.	Optical performance, NVIS radiance, heater performance, EMI shielding, coatings, interfaces, qualification, inspection and change control.

1.1 Safety allocation precedes display allocation

The system safety process identifies whether display loss, corruption, latency or misleading presentation creates minor, major, hazardous or catastrophic effects. That classification drives independence, monitoring, reversion, design assurance levels, verification rigor and the amount of supplier data required. The display provider should receive the requirements needed to preserve the allocated safety objectives, but the integrator retains responsibility for the aircraft- or vehicle-level safety case.

- Loss of display, intermittent blanking and reset behavior.
- Frozen, stale, incorrect, mis-scaled or mis-registered information.
- Incorrect color or alert prioritization, missing annunciation and latent failures.
- Common-cause effects from shared power, video, cooling, software, FPGA or optical enhancements.
- Reversionary modes, degraded modes and recovery time.

2. U.S. civil airborne display requirements

U.S. civil installation approval is based on the applicable amendment level of 14 CFR and the aircraft certification basis. The following sections are the principal starting points; project-specific special conditions and issue papers may add requirements.

Aircraft category	Principal display-related requirements
Part 25 transport airplanes	§§25.1301, 25.1302, 25.1303, 25.1309, 25.1316, 25.1317, 25.1321, 25.1322, 25.1331 and 25.1381.

Aircraft category	Principal display-related requirements
Part 23 airplanes	§§23.2605, 23.2610 and 23.2615, together with FAA-accepted means of compliance for the applicable aircraft level.
Part 27 and Part 29 rotorcraft	Equipment/system safety, arrangement and visibility, warning/caution color, instrument lighting, HIRF, lightning and installation requirements.

Primary sources: [R1] through [R4].

2.1 Installation and human-machine-interface expectations

- Information must be clear, unambiguous, visible and usable from the intended crew positions over the operational lighting and viewing envelope.
- Controls and displayed information must support expected crew capabilities and minimize reasonably foreseeable errors.
- Warning, caution, advisory and normal indications must be differentiated consistently. Part 25 conventionally reserves red for warnings and amber/yellow for cautions.
- Readability must address direct sun, diffuse ambient illumination, reflections, glare, polarization, viewing angle, night dimming and required crew eyewear.
- The system must identify loss, invalid or misleading information commensurate with the hazard classification and support safe reversion or continued operation.
- Response time, data age, latency, update rate and motion artifacts must be suitable for the displayed function.

2.2 FAA guidance and article approvals

FAA AC 25-11B remains the central transport-category flight-deck-display guidance. It is supplemented by AC 25.1302-1 for flightcrew interaction, AC 25.1322-1 for alerting and AC 23.1311-1C for Part 23 electronic displays. Specialized guidance applies to synthetic vision, enhanced vision, electronic maps and head-up displays.

Display article	Common approval basis	Important limitation
Multipurpose head-down electronic display	TSO-C113b using SAE AS8034C	Article approval does not approve the aircraft installation.
Electronic flight instrument system display	TSO-C209	Installation-level intended functions and failure effects remain to be approved.
Electronic map	TSO-C165b using RTCA DO-257B	Map data, declutter, currency and source annunciation must be addressed.
Head-up display	TSO-C210	Field of view, head motion box, conformality and external-scene interaction require installation evaluation.
Civil night-vision goggles	TSO-C164 series using RTCA DO-275	Aircraft lighting compatibility and operational approval remain separate.

Primary sources: [R5] through [R8].

2.3 Development assurance and environmental qualification

- RTCA DO-178C for airborne software, recognized through FAA AC 20-115D.
- RTCA DO-254 for airborne electronic hardware, recognized through FAA AC 20-152A.
- SAE ARP4754A through current FAA AC 20-174. ARP4754B may be proposed but should be agreed with the certification authority.
- SAE ARP4761 or an authority-agreed successor for safety assessment.
- RTCA DO-160G for environmental, electrical and EMC qualification using installation-appropriate categories.
- DO-326A, DO-356A and DO-355 for connected-system security when included in the project certification basis or special conditions.

Primary sources: [R9] through [R12].

3. European civil airborne display requirements

EASA certification follows Regulation (EU) 2018/1139, Part 21 and the applicable Certification Specifications. The relevant CS amendment level is established by the project certification basis, not simply by the latest publication date.

Category	Current publication snapshot as of 16 August 2026
Small aeroplanes	CS-23 Amendment 6, April 2026.
Large aeroplanes	CS-25 Amendment 28.
Small rotorcraft	CS-27 Amendment 10.
Large rotorcraft	CS-29 Amendment 12.

Primary sources: [R13] through [R16].

3.1 Display and alerting expectations

The EASA CS requirements parallel the FAA principles for intended function, safety, arrangement, visibility, flightcrew interaction, alerting, instrument lighting, lightning and HIRF. CS 25.1322 uses red for warnings, amber/yellow for cautions and permits advisory colors other than red or green; monochrome systems require other clearly distinguishable coding.

3.2 ETSO and AMC framework

The common European article approvals are ETSO-C113b for multipurpose electronic displays, ETSO-C165b for electronic maps, ETSO-C209 for EFIS displays, ETSO-C210 for HUDs and ETSO-C164 for NVGs. An ETSO authorization is an article approval and does not establish suitability for a particular installation.

- AMC 20-115D: ED-12C/DO-178C software assurance.
- AMC 20-152A: ED-80/DO-254 airborne electronic hardware assurance.
- ED-14G/DO-160G: environmental qualification.
- ED-79A/ARP4754A and the accepted safety-assessment process, unless an alternative revision is agreed for the project.
- AMC 20-42: ED-202A/DO-326A, ED-203A/DO-356A and ED-204/DO-355 aircraft information security.

Primary sources: [R17] through [R20].

4. Civil NVIS and NVG installations

NVIS is a system property
Compatibility must be demonstrated for the actual NVGs, cockpit lighting, display optical stack, indicators, utility lights, windscreens, reflections, external lighting, operating modes and crew tasks. A component-level NVIS-radiance report is necessary but not sufficient.

4.1 United States

- NVGs conforming to the applicable TSO-C164 series and RTCA DO-275 minimum operational performance standard.
- Lighting and display modification approved through the aircraft TC or STC process.
- Ground daylight-readability, night-unaided and night-aided evaluations.
- Flight evaluation for blooming, halo, reflections, windshield effects, external-light interference, focus, workload and emergency/reversion behavior.
- Instructions for Continued Airworthiness addressing filters, optical degradation, replacement parts and inspection intervals.
- Operator authorization, training and maintenance approval as applicable to the operating rules.

The FAA publishes current NVIS evaluation checklists and policy material on its NVIS certification page [R21].

4.2 Europe

For applicable helicopter operations, EASA Part-SPA requires specific NVIS operational approval and an approved airworthiness configuration. The installation typically includes compatible panel and instrument lighting, utility lighting, flashlights, external lighting and the means to extinguish incompatible sources. The operational package addresses compatible NVGs, radio-altimeter alerts where required, training and continuing airworthiness.

Primary sources: EASA Air Operations Part-SPA and CM-FT-001 [R22], [R23].

4.3 NVIS requirements allocated to the display provider

Provider requirement	Required definition or evidence
NVIS standard and configuration	Applicable MIL-STD-3009, DO-275/TSO-C164 or program-specific class, color set, NVG model and aided/unaided modes.
Spectral performance	NVIS radiance, spectral radiance data, chromaticity and measurement uncertainty at required drive levels, colors, temperatures and viewing angles.
Low-luminance performance	Minimum/maximum luminance, dimming law, uniformity, gray-scale/color tracking, flicker and temporal stability at the lowest usable levels.
Mode integrity	Transition time, inadvertent-mode prevention, mode annunciation, power-up default, failure state and independence of dual-mode circuitry.
Optical artifacts	Blooming, halo, light leakage, bright defects, reflections, filter nonuniformity and interaction with touch, heaters, EMI layers and coatings.
Configuration control	Controlled filter construction, LEDs, phosphor, polarizer, adhesives, coatings, firmware and any component that can change spectrum or luminance.

5. U.S. military airborne display requirements

Each U.S. military service or delegated airworthiness authority establishes the certification basis. MIL-HDBK-516D provides foundational criteria but is guidance until specific criteria are selected and made part of the program airworthiness basis.

Area	Current principal document	Application note
Airworthiness criteria	MIL-HDBK-516D, 29 May 2026	Select and tailor criteria; the handbook is not automatically a contractual requirement.
NVIS lighting/displays	MIL-STD-3009, Notice 2 validation 2024	Applies to aircraft lighting environments and equipment contributing to them.
Legacy Navy NVIS	MIL-L-85762A	Use where explicitly invoked; do not silently substitute for MIL-STD-3009.
Display symbology	MIL-STD-1787D	Program access and distribution controls may apply.
Human engineering	MIL-STD-1472H, Notice 1, April 2026	Tailor to crew station, task, controls and display arrangement.
Environment	MIL-STD-810H Change 1	Tailor methods, procedures and severities to the life-cycle environment.
Equipment EMI/EMC	MIL-STD-461H, 17 April 2026	New revision; confirm contract transition from 461G.
Platform E3	MIL-STD-464D, Notice 1, February 2026	System-level electromagnetic environmental effects.
Aircraft power	MIL-STD-704F, Notice 4, June 2026	Flow applicable power-quality and transient requirements to equipment.
System safety	MIL-STD-882E Change 1	Supports hazard identification and risk acceptance.

Primary source for current military document status: DLA ASSIST/Quick Search [R24] through [R32].

5.1 Military display-specific focus

- Readable mission and flight symbology under daylight, night, NVIS, degraded and emergency modes.

- Specified contrast, luminance, dimming, color, viewing envelope, response and image retention over temperature and life.
- NVIS spectral compatibility at the complete installed lighting-system level.
- Mission-data integrity, latency, video loss/freeze detection and reversion behavior.
- Environmental tailoring for vibration, gunfire vibration where applicable, crash shock, altitude, rapid decompression, fluids, fungus, salt fog, rain and sand/dust.
- Equipment-level EMI plus platform-level bonding, grounding, cable shielding, lightning and E3 requirements.

6. European military airborne display requirements

Military and other state aircraft are generally outside EASA civil jurisdiction. Each national Military Aviation Authority establishes and approves the certification basis. The European Defence Agency Military Airworthiness Authorities Forum provides harmonized EMAR material, but member states must implement it nationally before it becomes binding.

Framework	Current role
EMAR 21 Edition 3.0, May 2025	Harmonized military certification procedures and organization requirements.
EMAR 21 AMC/GM Edition 3.0, October 2025	Acceptable means and guidance supporting EMAR 21.
EMACC	Framework for developing a military aircraft certification basis using selected civil and military criteria.
EASA CS/ETSO/AMC	Frequently selected where suitable, with military deltas added by the national authority.
NATO and national standards	STANAG/AECTP and standards such as UK Def Stan 00-970, 00-35 and 59-411 when ratified and contractually invoked.

Primary source: European Defence Agency MAWA documents page [R33].

For NVIS, a program may invoke STANAG 3800, MIL-STD-3009 or a national standard. The controlled NATO edition, national ratification and contract revision should be verified before requirements are flowed to suppliers.

7. Ground and vehicle-mounted display systems

7.1 Military ground vehicles and mission consoles

Requirement area	Typical U.S. baseline	European/NATO consideration
Human engineering	MIL-STD-1472H	National human-factors rules or contract-selected MIL-STD-1472H.
Environment	MIL-STD-810H Change 1	STANAG 4370/AECTP, Def Stan 00-35 or national equivalent.
EMI/EMC	MIL-STD-461H and MIL-STD-464D	National EMC standards, STANAG/AECTP or Def Stan 59-411.
Vehicle power	MIL-STD-1275F for 28 VDC tactical vehicles	National vehicle power specification or NGVA electrical architecture.
Architecture	VICTORY where required	NATO Generic Vehicle Architecture, STANAG 4754, where ratified and invoked.
Safety/security	MIL-STD-882E plus program cybersecurity	National safety/security requirements and NATO security constraints.

Primary sources: DLA Quick Search and NATO publications [R28], [R29], [R32], [R34], [R35].

Ground-vehicle NVIS caution
MIL-STD-3009 is scoped to aircraft lighting. A ground program may tailor and invoke it, but should define the actual crew-station test method, windows, blackout mode, exterior lighting, warning lamps and reflected sources rather than treating aircraft compliance as automatic.

7.2 Civil road vehicles

Market	Binding or type-approval requirements	Common engineering standards
United States	FMVSS 101 for control/display identification, illumination and color; FMVSS 111 for rear visibility; FCC Part 15 for electronic/radio equipment.	ISO 16750, ISO 26262, ISO/SAE 21434 and SAE J1455 where selected by the OEM.
European Union/UNECE	EU Regulations 2018/858 and 2019/2144; UNECE R10 EMC; R155 cybersecurity and R156 software updates for applicable vehicles.	ISO 16750, ISO 26262 and ISO/SAE 21434.

Primary sources: [R36] through [R39].

A permanently installed automotive display normally follows the vehicle type-approval framework. Generic CE marking does not replace vehicle approval. Standalone products may additionally fall under the EU EMC, Radio Equipment, Low Voltage and RoHS Directives, depending on configuration and exclusions.

7.3 Aerospace ground stations and support equipment

- A UAS ground-control display that is part of the type design is assessed as a safety-significant system, including loss of link, misleading information, data age, latency and human factors.
- Safety-related CNS/ATM ground displays may use RTCA DO-278A/EUROCAE ED-109A software assurance and ATM/ANS-specific authority requirements.
- Maintenance and test displays that can affect conformity require controlled approved data, calibration, configuration control and quality-system evidence.
- Non-safety office or portable displays generally follow commercial EMC, electrical and radio requirements rather than aircraft airworthiness requirements.

8. Requirements passed from the system designer to the display provider

The display-provider specification should translate aircraft, vehicle, crew-station and safety requirements into measurable component or assembly requirements. It must also identify which requirements cannot be closed by the supplier and therefore remain installation-level verification responsibilities.

8.1 Display acquisition categories

Category	Typical scope	Primary control risk
OEM COTS	An unmodified commercial LCD, OLED or module purchased to the manufacturer data sheet.	Limited design data, silent component changes, short life cycle, broad data-sheet tolerances and insufficient environmental evidence.
Value-added enhanced COTS	COTS display with a controlled high-bright backlight, NVIS filter/mode, optical bond, cover window, transparent conductive heater, EMI shield, touch sensor or mechanical integration.	The provider must control both the OEM baseline and every added material/process; qualification must address interactions among enhancements.
Custom display	A purpose-developed LCD, OLED or MicroLED device/module with custom glass, pixel format, drive electronics, optical stack, backlight or package.	NRE, tooling ownership, yield, minimum order, long-term supply, qualification scope and access to design/production data.
Rear projection	Projector, illumination source, imaging engine, relay optics, screen, alignment structure and thermal control.	Alignment stability, focus, uniformity, stray light, contrast, source life, optical contamination and calibration over environment.

8.2 Responsibility allocation

Requirement	Display provider	System integrator
Panel/module conformance	Verify controlled drawing, BOM, workmanship and unit-level acceptance.	Approve source and configuration; evaluate installation suitability.
Optical performance	Demonstrate luminance, contrast, reflectance, color, uniformity, viewing angle, response and defects under specified conditions.	Demonstrate readability and task performance in the installed ambient/viewing geometry.
NVIS	Provide component spectral, color, dimming and mode evidence against flowed-down limits.	Perform complete cockpit/crew-station aided and unaided evaluations and obtain approval.
EMI shielding	Verify layer resistance, continuity, transmission and defined coupon/assembly shielding performance.	Verify enclosure, bezel, bonding, grounding, cable and platform-level EMC/E3 performance.
Environmental qualification	Qualify the defined display assembly to flowed-down categories and severities.	Confirm categories represent the installed environment and address installation-specific effects.
Safety and failure behavior	Provide failure modes, monitoring behavior, analyses and design-assurance evidence within scope.	Own the aircraft/vehicle hazard assessment, allocation and integrated safety case.
Configuration/lifecycle	Control OEM source plus all enhancements; issue change notices and obsolescence data.	Approve changes, manage requalification and maintain approved configuration.

8.3 Baseline functional and interface requirements

- Mechanical envelope, active area, bezel opening, mounting datums, mass, center of gravity, fastener limits, connector access and service clearances.
- Pixel format, physical pixel pitch, color depth, subpixel arrangement, scan direction, image orientation, scaling behavior and accepted video timings.
- Video and control interfaces, connector part numbers, pin assignment, signal integrity, EDID/configuration data, command protocols and power sequencing.
- Input voltage, steady-state and transient power, inrush, brownout, hold-up, reverse polarity where applicable, grounding, bonding and leakage current.
- Power-up, image-valid, reset, mode-transition and recovery timing; behavior for missing, malformed, stale or out-of-range video.
- Built-in test, health/status reporting, fault isolation, maintenance access and stored configuration or calibration data.

8.4 Optical and visual performance

A center-screen white-luminance number is not an adequate sunlight-readability requirement. Readability depends on emitted luminance, diffuse and specular reflectance, ambient illumination geometry, contrast, color separation, viewing angle and the optical stack. The supplier specification should define the measurement geometry and acceptance limits for each operating mode.

Characteristic	Specify at minimum
Luminance	Minimum, typical and maximum; center and uniformity; full-white and representative content; temperature, voltage, aging and viewing-angle conditions.
Dimming	Continuous/step range, lowest usable level, transfer curve, resolution, tracking, hysteresis, transition rate, flicker and external dim-command behavior.
Contrast/readability	Dark-room contrast plus ambient contrast under defined illuminance, source angle, observer angle, screen tilt, image content and eyewear.
Reflectance	Total hemispherical/diffuse and specular components, color dependence, incidence angle and polarization, including cover, touch, heater, shield and bond.
Color	Chromaticity coordinates, gamut or required colors, white point, primary/secondary color tolerances, color difference and tracking over temperature/drive.

Characteristic	Specify at minimum
Viewing envelope	Luminance, contrast, color shift, gray-scale inversion and readability across horizontal, vertical and cross-cockpit viewing positions.
Uniformity/artifacts	Luminance/color uniformity, mura, light leakage, hot spots, backlight pattern, pressure sensitivity, rainbow, moire and Newton rings.
Temporal performance	Rise/fall response, overshoot, motion artifacts, sample-and-hold effects, latency and low-temperature behavior.
Defects	Bright/dark/stuck subpixels, clusters, line defects, contamination, bubbles, bond voids, coating defects and active-area zoning.

Useful measurement references include SAE ARP4260/ARP4260A, SAE AS8034C, ARP4256A and applicable IEC display-device measurement standards [R6], [R40] through [R42].

8.5 Technology-specific requirements

Technology	Additional requirements or risks
LCD	Backlight spectrum/life, polarizer degradation, low-temperature response, inversion, viewing-angle compensation, light leakage, cell gap, pressure sensitivity and backlight-replaceability.
OLED	Differential aging, image retention/burn-in, compensation algorithm, peak versus sustained luminance, automatic brightness limiting, lifetime by content/temperature, moisture sensitivity and dark-level behavior.
MicroLED	Pixel/subpixel yield, repair strategy, uniformity calibration, color and luminance drift, dead-pixel growth, driver architecture, thermal density and production-lot consistency.
Rear projection	Source life, optical alignment, focus, field curvature, screen gain/viewing cone, hot spots, keystone/distortion, stray light, contamination, thermal drift and calibration retention.

8.6 High-brightness and enhanced backlights

- Define minimum delivered luminance after all filters, shields, touch layers, cover glass and bonding—not bare-panel or LED-engine output.
- Specify luminance and color uniformity, thermal derating, automatic brightness limiting, junction-temperature margin and behavior at maximum ambient temperature.
- Define LED binning, spectrum, lot mixing, color shift, drive current, PWM frequency, dimming resolution, audible noise and camera/NVG beat or flicker risks.
- Specify useful life to a defined luminance/color endpoint at representative temperature and duty cycle, including replaceable-backlight strategy if used.
- Verify that increased brightness does not create unacceptable night minimums, reflections, local heating, power transients or accelerated optical degradation.

8.7 NVIS-enhanced and dual-mode displays

- Define whether compatibility is achieved by filtered backlight, switchable illumination path, optical filter, color transformation or combined architecture.
- Specify aided and unaided mode luminance, chromaticity, NVIS radiance and uniformity for each required color and drive level.
- Control LED, phosphor, filter, polarizer, adhesive and coating substitutions because small spectral changes can invalidate NVIS results.
- Define transition time, default mode, annunciation, inadvertent selection prevention and failure behavior.
- Verify daylight readability and color discrimination after the NVIS construction is applied; NVIS filters can reduce luminance and alter color/reflectance.

8.8 Transparent conductive heaters

A transparent heater is normally implemented with ITO or another conductive transparent layer on a cover or internal optic. The supplier specification should include:

- Minimum operating/start temperature, warm-up time, target temperature and allowable thermal gradient.
- Sheet resistance, busbar geometry, resistance tolerance, operating voltage/current, inrush and maximum power.
- Temperature sensing, control algorithm, overtemperature protection, open/short failure behavior and local hot-spot limits.
- Optical transmission, reflection, color shift, haze, pattern visibility and optical distortion over temperature.
- Environmental durability, thermal cycling, adhesion, humidity, edge sealing, electrical isolation and dielectric withstand.
- EMI emissions/susceptibility from heater drive and interaction with touch or EMI-shield layers.

8.9 Transparent EMI/RFI shielding

Helicopter and other rotorcraft installations can combine severe vibration with demanding EMC, HIRF, lightning and platform E3 constraints. A transparent shield may use ITO, fine conductive mesh or a hybrid construction. The flowed-down requirement must cover the complete electrical path, not only the optical coating.

- Shielding effectiveness versus frequency, polarization, aperture and installation geometry.
- Sheet resistance or mesh resistance; conductive busbar design; continuity to frame; bonding and grounding interface.
- Optical transmission, reflection, haze, color shift, moire and interaction with pixel pitch, touch sensors and polarization.
- Corrosion, galvanic compatibility, edge termination, seal integrity and resistance stability after environment.
- Coupon, subassembly and installed-system test methods; acceptance limits should not be inferred from coating resistance alone.

8.10 Optical bonding and cover windows

- Glass or polymer type, thickness, temper/chemical strengthening, flatness, wedge, edge treatment and impact requirement.
- Bond material, bond-line thickness and tolerance, refractive index, transmission, haze, color, cure, outgassing and flammability.
- Bubble, void, contamination and delamination limits by viewing zone; cosmetic limits should distinguish bond defects from substrate defects.
- Thermal-expansion mismatch, pressure/altitude behavior, humidity ingress, yellowing, UV/solar exposure and repairability.
- Touch, heater, EMI shield, AR/HEA and NVIS-stack order must be controlled because optical and electrical interactions depend on layer sequence.

8.11 Coatings and spectral layers

Layer	What the drawing/specification should define
HEA or AR coating	Substrate and coated surface; wavelength band; maximum average and peak reflectance; incidence/viewing angle; polarization; transmission; color; environmental durability; cleanability; allowable cosmetic defects. Do not specify only a marketing name such as HEA.
ITO	Function as heater, EMI shield or both; sheet resistance and uniformity; transmission/reflectance/haze; color; pattern/busbar geometry; isolation; grounding; adhesion and environmental stability.
Hot mirror	Visible passband, IR rejection/reflection band, spectral transition, incidence-angle shift, polarization, absorbed heat, substrate temperature, reflected-energy path and NVIS impact.
Hard/oleophobic/ hydrophobic layer	Hardness/abrasion, adhesion, contact angle if relevant, chemical resistance, cleanability, touch friction and optical effect after durability testing.

Layer	What the drawing/specification should define
EMI mesh	Material, pitch, line width, orientation, sheet/contact resistance, busbar, optical transmission, moire limit, corrosion protection and grounding interface.

Current ISO coating references include ISO 9211-2:2024 for optical properties, ISO 9211-3:2024 for environmental durability, ISO 9211-4:2022 for abrasion/adhesion/water test methods and ISO 9211-5:2018 for minimum requirements for antireflecting coatings. Legacy military coating specifications may remain valid when explicitly invoked but should not automatically be selected for new designs.

Primary sources: ISO 9211 series [R43] through [R46].

8.12 Scratch-and-dig and ISO surface-imperfection requirements

Do not make an undocumented conversion
MIL-PRF-13830B scratch-and-dig and ISO 10110-7 surface-imperfection notation use different classification and inspection concepts. A value in one system should not be converted to the other without an explicitly agreed method and acceptance study.

Specification system	Use and required clarification
MIL-PRF-13830B	Traditional scratch-and-dig notation such as 60-40. Scratches are visibility/comparison based while digs are size based. The specification is active, but the drawing must identify applicable surface, clear aperture, zones and inspection conditions.
ISO 10110-7:2017	Drawing indication for acceptability of localized imperfections, edge chips and long scratches within a defined test region. Select the applicable visibility or dimensional approach and use the standard's notation.
ISO 14997:2017	Test methods supporting evaluation of optical-surface imperfections, including visual/visibility inspection approaches.
ISO/TR 14997-2:2022	Guidance for machine-vision evaluation. If automated inspection is used, define system resolution, calibration, detection threshold, repeatability and correlation to the contractual acceptance method.

Primary sources: DLA MIL-PRF-13830 status and ISO publications [R47] through [R50].

For display windows and bonded assemblies, the specification should additionally define inspection illumination, background, observation distance, magnification, angle, viewing zones, clear aperture, edge exclusion, allowable aggregation, coating artifacts, bond voids and whether inspection is performed with the display off, illuminated or both. Pixel defects, mura and contamination require separate criteria even if the cover optic meets its surface-imperfection requirement.

8.13 Example supplier 'shall' requirements

The following examples are intentionally parameterized. Bracketed values must be replaced by program-specific limits and conditions.

- The display assembly shall provide a minimum white luminance of [X cd/m²] at [specified video pattern], measured normal to the display after all cover, touch, heater, EMI, NVIS and bonding layers, over [temperature/voltage/life conditions].
- The display assembly shall maintain an ambient contrast ratio of at least [X:1] for [specified foreground/background colors] at [illuminance], with the source at [angle], observer at [angle] and the display at [tilt/orientation].
- In NVIS mode, each required color shall meet the applicable [MIL-STD-3009 or DO-275] NVIS-radiance and chromaticity limits over [dimming range, temperature, voltage and viewing envelope].
- The transparent heater shall raise the optical stack from [minimum soak temperature] to [minimum operating temperature] within [time] while limiting local surface temperature to [maximum] and thermal nonuniformity to [maximum delta].
- The transparent EMI shield shall provide at least [dB] shielding effectiveness over [frequency range] when bonded to the specified frame interface, while maintaining at least [percent] photopic transmission and no objectionable moire over the viewing envelope.

- The AR/HEA-coated surface shall have average photopic reflectance no greater than [percent] and peak reflectance no greater than [percent] over [wavelength band], [incidence range] and [polarization conditions], before and after specified durability tests.
- The supplier shall not change the LCD/OLED/MicroLED source, timing controller, polarizer, backlight LED/phosphor, optical filter, adhesive, coating, heater, shield, touch sensor, firmware or manufacturing location without prior written approval and an approved requalification assessment.

9. Qualification, acceptance and compliance evidence

9.1 Verification levels

Level	Purpose	Typical evidence
Analysis	Allocate safety, thermal, optical, power and EMC requirements and justify margins.	Calculations, models, component derating, FMEA/FMECA, reliability and safety analyses.
Coupon/material	Characterize coatings, adhesives, heaters, shields and optical materials.	Spectral data, sheet resistance, adhesion, abrasion, humidity, thermal-cycle and chemical-resistance reports.
Display assembly	Verify the controlled supplier configuration.	Optical/electrical ATP, environmental qualification, EMI, NVIS and workmanship evidence.
Installed system	Demonstrate intended function and integration.	Cockpit/crew-station readability, aided/unaided NVIS, platform EMC/E3, flight/vehicle test and certification compliance.
Production acceptance	Prevent drift in delivered units.	Lot tests, calibrated inspection, control charts, certificates of conformance and serialized results.
Continued airworthiness/lifecycle	Maintain approved performance after changes and aging.	ICA, requalification plan, approved substitutions, repair limits, inspection intervals and obsolescence control.

9.2 Environmental qualification matrix

The system designer should issue an environmental qualification form or matrix that identifies every applicable section, method, procedure, category and severity; the installation zone; the test-unit configuration and operating mode; and quantitative pass/fail criteria. ‘Meets DO-160,’ ‘ED-14 qualified’ or ‘tested to MIL-STD-810’ is not an adequate supplier requirement.

Planning baselines—not universal qualification levels

The values below are common starting envelopes for requirements development and supplier screening. They do not replace aircraft- or vehicle-specific tailoring. For civil airborne equipment, DO-160/ED-14 categories are selected from aircraft type, intended function, installation zone and certification basis. MIL-STD-810 methods and severities are tailored from the life-cycle environmental profile. The contractually controlled environmental qualification matrix governs.

9.2.1 Applicability and flowdown boundary

The system specification should separate what the display provider can close on the controlled display assembly from what the aircraft or vehicle integrator must close after installation. A value-added supplier should qualify the finished delivered stack—not merely rely on evidence for the unmodified commercial panel.

Platform/use	Common starting standards	How levels are selected	Qualification boundary
General aviation / civil airborne	RTCA DO-160G / EUROCAE ED-14G; applicable 14 CFR or CS basis	Aircraft type, pressurized/unpressurized zone, installation location, intended function and failure effect	Provider closes declared equipment categories. Applicant/integrator closes installation, aircraft safety, cooling, HIRF/lightning and installed readability as applicable.
Military aircraft	MIL-STD-810H Change 1; MIL-STD-461H; MIL-STD-704F; MIL-STD-464D; service airworthiness criteria	Mission profile, aircraft zone, measured platform data, service tailoring and safety/mission criticality	Provider closes equipment tests and interfaces. Platform authority closes E3, aircraft power quality, mounting, harness, cooling and mission installation.

Platform/use	Common starting standards	How levels are selected	Qualification boundary
Military ground / rugged land	MIL-STD-810H Change 1; MIL-STD-461H; MIL-STD-1275F; MIL-STD-464D where invoked	Installed, transported and stored life-cycle profiles; vehicle class; mounting; exposure; crew and mission needs	Provider closes unit-level environment and interfaces. Vehicle integrator closes installed vibration/shock, ground/bonding, antenna/E3 and platform power interactions.
Civil road / industrial land	OEM specification; ISO 16750 and ISO 7637 families where invoked; applicable EMC/safety rules	Mounting location, vehicle voltage, climatic zone, road profile, enclosure and service life	Use the customer-controlled profile; do not substitute military severities or component data without an approved equivalence analysis.

- **Supplier flowdown — Identify the delivered configuration by part number and revision, including panel, backlight, NVIS filter, touch sensor, heater, EMI shield, optical bond, cover window, coatings, bezel/frame, controller, firmware and harness simulator. State which requirements remain for installation-level closure.**

9.2.2 Temperature, altitude and combined environments

Condition	General aviation / civil airborne planning baseline	Military-aircraft planning baseline	Land-system planning baseline
Ground survival / storage	Benign cabin/portable articles may begin near −20 to +55 °C. Rugged or exposed installed displays commonly begin near −55 to +85 °C; selected DO-160/ED-14 Section 4 category governs.	−55 to +85 °C is a common screening envelope; tailor for global ground extremes, solar load, ramp soak and local equipment-bay heating (MIL-STD-810 Method 501.7/502.7).	Sheltered systems may begin near −20 to +55 °C. Tactical/exposed systems commonly begin near −51/−55 to +85 °C storage/survival; tailor by climatic design type and transport/storage profile.
Operating temperature	Rugged cockpit equipment often begins near −40 to +70 °C; use the selected Section 4 category, local cooling/heating and duty cycle. Declare cold-start and hot-start behavior.	−40 to +71 °C is a common starting range; more severe localized zones may apply. Tailor Method 501.7/502.7 procedures, stabilization, power state and ramp rates.	Tactical/exposed equipment commonly begins near −40 to +71 °C; sheltered installations may be narrower. Include solar/local engine heat and enclosure rise.
Altitude / low pressure	Declare pressurized or unpressurized zone. Common equipment ceilings span roughly 15,000 to 55,000 ft depending aircraft and location; selected Section 4 category governs.	About 50,000 to 70,000 ft is a common planning range for aircraft equipment, but mission altitude and zone control Method 500.6 pressures and durations.	Operation to about 15,000 ft is a common high-terrain baseline. Air transport/storage can require 40,000 to 50,000 ft equivalent altitude; define powered state.
Rapid decompression	Apply where a pressurized-zone failure can expose the equipment or create a hazard. Define cabin starting pressure, aircraft maximum altitude, transition time and powered function per Section 4.	Define cabin-to-mission-altitude transition—often 40,000 to 60,000 ft or higher—at the program-specified seconds; Method 500.6 Procedure III where applicable.	Normally not an installed ground requirement; apply for air-transported/shelter equipment when credible, using Method 500.6 Procedure III and the airlift profile.
Temperature variation / thermal shock	Select DO-160/ED-14 Section 5 category and powered/unpowered state. Include cold-to-warm condensation risk and rapid cockpit thermal transitions.	Tailor Method 503.7 procedures, transfer time, dwell, number of cycles and operation. Use measured rates if a pod, canopy, ramp or bay creates rapid transitions.	Tailor Method 503.7 for cold soak to heated shelter/vehicle, solar-to-rain transitions and logistics exposure; include condensation inspection.
Combined environments	Individual DO-160/ED-14 sections are normally used unless analysis shows an interaction requiring a combined test. Consider temperature plus power/load and altitude plus cooling.	Use Method 520.4 and/or 523.4 only where the life-cycle profile identifies credible combined temperature, altitude, vibration, acoustic or other interactions.	Combine temperature, humidity, solar, power and vibration only when representative of the installed or transport state; define sequence and cumulative damage rationale.

- **Supplier flowdown — State chamber air temperature versus display hot-spot limits; stabilization rule; ramp rate; dwell; cycles; powered modes; cold/hot start time; heater-control behavior; luminance/color/touch checks; and post-test inspection of seals, polarizers, coatings and optical bonds.**

9.2.3 Vibration, shock, crash safety and transportation

Condition	General aviation / civil airborne planning baseline	Military-aircraft planning baseline	Land-system planning baseline
Operational vibration	DO-160/ED-14 Section 8 category is selected by fixed-wing/rotorcraft type, mounting and equipment location. Use measured aircraft spectra where the standard category is not representative.	MIL-STD-810 Method 514.8 profile/category tailored by aircraft type, zone, mounting and mission hours. Rotorcraft displays should use measured narrow-band/rotor harmonics when available.	Method 514.8 installed profile tailored by vehicle class, road/track use, mounting stiffness and mission duration. Verify image stability, connectors, fasteners and intermittent faults while operating.

Condition	General aviation / civil airborne planning baseline	Military-aircraft planning baseline	Land-system planning baseline
Operational / functional shock	DO-160/ED-14 Section 7. A representative screening declaration sometimes starts near 6 g for 11 ms, but the selected category, waveform and aircraft basis govern.	Method 516.8 functional shock, with waveform, peak, duration, axes and number of shocks tailored to the aircraft and installed mount.	Method 516.8 functional shock for pothole/curb/tactical events, tailored to the measured or specified mount input; include operation during/after shock.
Crash safety / acceleration	DO-160/ED-14 Section 7 crash-safety impulse and sustained loads as selected. A 20 g, 11 ms impulse is a common screening reference—not a universal certification value.	Use Method 513.8 acceleration and/or Method 516.8 crash-hazard procedures when invoked; service/platform crash loads and retention criteria control.	Vehicle crash/retention loads come from the platform safety basis. Apply Method 516.8 only where invoked; define no-detachment, no-hazard and post-event function criteria separately.
Gunfire vibration	Normally not applicable to general aviation; exclude explicitly unless a special mission installation creates the environment.	Method 519.8 where a gun, cannon or weapon firing environment couples into the display. Use firing rate, burst length, axes, rounds and measured spectra where available.	Apply Method 519.8 to weapon-mounted or weapon-adjacent land systems when credible; define firing configuration, ammunition, burst schedule and cumulative exposure.
Transportation / transit drop	Define packaged shipping vibration, handling/drop and air-freight altitude separately from installed-aircraft qualification.	Method 514.8 transport procedures and Method 516.8 transit-drop/bench-handling procedures as applicable; test packaged, containerized or installed state stated by the logistics profile.	Method 514.8 Procedures I/II/III as installed, secured cargo or loose cargo; Method 516.8 transit drop/handling. State packaging, orientation, tie-down and accumulated distance.

- **Supplier flowdown — Define input/control point, fixture and mount stiffness, axes, spectrum or pulse, tolerances, duration, temperature if combined, powered image patterns, camera/photodiode monitoring for blanking or flicker, connector monitoring and acceptance after each axis.**

9.2.4 Moisture, contamination and climatic exposure

Condition	General aviation / civil airborne planning baseline	Military-aircraft planning baseline	Land-system planning baseline
Humidity / condensation	DO-160/ED-14 Section 6 category selected by location. Include operation after exposure and inspect optical bond, polarizer, touch stack and corrosion paths.	MIL-STD-810 Method 507.6, tailored cycle count/severity and powered state; Method 524.1 where freeze/thaw or fogging is credible.	Method 507.6 for tropical/storage/vehicle exposure; Method 524.1 for cold-to-warm fogging. Declare recovery time and readability during condensation where required.
Fluids susceptibility	DO-160/ED-14 Section 11 fluids selected from actual installation/maintenance exposures: fuel, hydraulic fluid, oils, cleaners, de-icing fluid, disinfectants and crew-contact fluids.	Method 504.3 fluids and exposure sequence tailored to aircraft servicing, maintenance and mission chemicals; include gasket, coating, label and bond-line inspection.	Method 504.3 for fuels, lubricants, hydraulic/coolant fluids, cleaners, insect repellent and decontaminants as credible. State splash, immersion or wipe method.
Fungus	DO-160/ED-14 Section 13 where material composition or warm/humid service makes it applicable; material certification may support analysis when accepted.	Method 508.8 where nutrient-supporting materials or tropical storage/operation are credible. Identify non-fungus-nutrient materials and coatings.	Method 508.8 commonly considered for tropical fielded equipment, textiles, seals, adhesives and coatings; tailor by materials and exposure.
Salt fog / corrosion	DO-160/ED-14 Section 14 for coastal, marine or salt-laden locations. Define connectors, grounding surfaces and cosmetic versus functional acceptance.	Method 509.8 (810H Change 1) for corrosive salt environments; test configuration should represent protective finishes, fasteners and galvanic couples.	Method 509.8 for coastal/amphibious/road-salt use where credible; include drain paths, enclosure interfaces, connectors and mounting hardware.
Sand and dust	DO-160/ED-14 Section 12 for exposed or poorly sealed locations; distinguish blowing dust from sand and declare fan/vent state.	Method 510.7 blowing dust and/or blowing sand procedures, with particle concentration, velocity, temperature, duration and operating state tailored to the zone.	Method 510.7 is common for tactical vehicles and outdoor consoles; include vents, fans, touch surface, controls and maintainability after ingress.
Rain / waterproofness	DO-160/ED-14 Section 10 category or installation-level enclosure test; define driven rain, drip, spray and drainage for exposed panels.	Method 506.6 rain, blowing rain or drip procedure selected from installed exposure. State panel angle, wind, spray, drains and operation.	Method 506.6 for exposed vehicle/outdoor equipment; combine with the required enclosure/IP claim only when both test bases and acceptance criteria are explicitly invoked.
Icing, freezing rain and dew	DO-160/ED-14 Section 24 only where icing is credible; Section 5/6 can address condensation/dew. Declare touch/readability and de-icing/heater needs.	Method 521.4 for icing/freezing rain and Method 524.1 for freeze/thaw or fogging, where credible. Define ice thickness, removal and safe operation.	Methods 521.4/524.1 for exposed land systems, especially covers, touchscreens, vents and heaters; define operability versus survival and allowable recovery.

Condition	General aviation / civil airborne planning baseline	Military-aircraft planning baseline	Land-system planning baseline
Solar radiation	Treat as installation/material requirement when direct sun is credible; use Method 505.7 or an approved equivalent for heating and actinic degradation. Do not confuse it with sunlight readability measurement.	Method 505.7 heating and/or actinic procedures tailored to canopy/exterior exposure, color/finish and mission geography; combine with powered thermal analysis as needed.	Method 505.7 is common for exposed consoles and vehicle panels; include surface temperature, solar loading, UV/color change and touchscreen/adhesive effects.

- **Supplier flowdown — Provide the exact fluids/materials, concentrations, application method, exposure/recovery sequence and cleaning allowed. Define sealing state, ports/caps, drains and operation. Acceptance should cover readability, touch/control function, corrosion, blistering, discoloration, coating adhesion, seal integrity and optical-bond defects.**

9.2.5 Power input and electromagnetic environment

Requirement	General aviation / civil airborne planning baseline	Military-aircraft planning baseline	Land-system planning baseline
Power input	DO-160/ED-14 Section 16 category for the actual 14/28 VDC or 115 VAC, 400 Hz/variable-frequency interface. Declare normal, abnormal, emergency, transfer, interruption and start behavior.	MIL-STD-704F aircraft interface—commonly 28 VDC and/or 115/200 VAC, 400 Hz or variable frequency—as invoked. Use the applicable MIL-HDBK-704 test guidance and aircraft-specific limits.	MIL-STD-1275F for 28 VDC military ground vehicles where invoked; otherwise customer/OEM voltage profile. Declare cranking, load dump, reverse polarity, interruption and recovery behavior.
Voltage spikes / transients	DO-160/ED-14 Section 17 category plus Section 16 transients as applicable. State source impedance, waveform, repetition and functional performance class.	Do not treat MIL-STD-704 as a complete voltage-spike requirement. Apply the program-selected 461/aircraft transient requirements and explicit waveforms at the equipment terminals.	MIL-STD-1275F transients for military 28 VDC systems; ISO 7637 family only when invoked for civil road systems. State coupling network, polarity, repetitions and recovery.
Audio-frequency / induced signals	DO-160/ED-14 Sections 18 and 19 with selected categories, pin groups, cable lengths, coupling method, dwell and performance criteria.	MIL-STD-461H applicability matrix commonly considers CS101 and related conducted-susceptibility tests; aircraft wiring/coupling requirements remain program-specific.	MIL-STD-461H conducted-susceptibility requirements as tailored; include MIL-STD-1275 power quality and vehicle-specific inductive loads where applicable.
RF susceptibility	DO-160/ED-14 Section 20 category. Declare conducted and radiated test levels, modulation, frequency range, cable setup and permitted degradation.	MIL-STD-461H commonly considers CS114/115/116 and RS103 as applicable; exact tests, curves and limits come from the procurement/platform matrix.	MIL-STD-461H CS/RS tests as tailored for vehicle radios, antennas and cable routing. Vehicle/platform field surveys can refine frequencies and levels.
RF emissions	DO-160/ED-14 Section 21 category with representative power, video content, dimming, touch and communications operating modes.	MIL-STD-461H commonly considers CE102 and RE102 as applicable; procurement matrix controls. Include switching backlight, heaters, touch, Ethernet/video and worst-case processing.	MIL-STD-461H CE/RE requirements as tailored; protect co-site radios, GNSS and platform sensors. Test all cable ports and worst-case display modes.
ESD	DO-160/ED-14 Section 25 at accessible controls, bezel, touchscreen and connectors; define powered state, discharge points and upset/recovery acceptance.	Apply MIL-STD-461H/program ESD requirement or service procedure where invoked; include operator touch points and maintenance connectors.	Apply program ESD and handling requirements; include gloved/bare operator touch, exposed I/O and service access. State no-damage and upset/recovery classes.
Lightning-induced / direct effects	DO-160/ED-14 Section 22 pin-injection/cable-bundle categories from aircraft lightning zoning and installation; Section 23 only for credible direct effects/exposure.	Aircraft lightning zoning and platform requirements allocate equipment/harness waveforms. Provider tests the declared unit/harness interface; platform authority closes installed protection.	Normally not an equipment requirement unless the land system has exposed cabling/antenna/lightning-protection needs; allocate surge and grounding from the site/vehicle design.
HIRF / E3	Aircraft safety assessment allocates HIRF. EASA AMC 20-158A relates DO-160/ED-14 Section 20 Category RR to HIRF Level 1 and Category TT to Level 3 where its conditions apply; final installation compliance remains with the applicant.	MIL-STD-461H is equipment/subsystem EMI. MIL-STD-464D is the platform/system E3 basis for HIRF, lightning, EMP, electrostatics and co-site effects as invoked. Keep the two matrices distinct.	MIL-STD-461H closes unit EMI; MIL-STD-464D closes platform E3 when invoked. Define antenna separation, bonding/grounding, cable shielding and vehicle/site-level verification ownership.

- **Supplier flowdown — The equipment specification should include standard/revision, test designator or DO-160/ED-14 category, exact curve/level/waveform, cable and grounding configuration, LISN/coupling devices, load and video modes, dimming/backlight/heater states, dwell, frequency steps and permitted performance degradation. For transparent ITO or mesh shielding, specify end-to-end shield termination and verify the complete electrical path—not only the optical coating.**

9.2.6 Flammability, smoke/toxicity, outgassing and optical bonds

Requirement	General aviation / civil airborne planning baseline	Military-aircraft planning baseline	Land-system planning baseline
Flammability	Applicable 14 CFR/CS material and installation requirements plus DO-160/ED-14 Section 26 when invoked. Section 26 Category C appears in some TSO/ETSO article requirements but is not universal. UL 94 alone does not establish aircraft compliance.	Use the service/platform material and fire-safety specification for the aircraft zone. Flow requirements to enclosure, PCB, wiring, optical films, adhesive, foam, labels and touch/bond materials.	Use the vehicle/shelter material and crew-compartment fire-safety basis. State flame spread/afterflame, dripping, ignition source and material thickness/configuration as applicable.
Smoke / toxicity	Apply only where the aircraft certification basis, cabin/interior location or customer specification invokes quantitative smoke/toxic-gas limits. Identify test method, specimen construction and limits.	Crew-station and enclosed-aircraft requirements are program/service specific. Do not infer compliance from flammability data; specify smoke density and toxic-gas methods separately.	Apply to enclosed crew compartments, shelters or mass-transit installations when invoked. Define combustion mode, gases, sampling time and acceptance limits.
Explosive atmosphere	DO-160/ED-14 Section 9 only for locations where flammable vapors can be present; declare normal/abnormal operating state and surface-temperature/arcing controls.	MIL-STD-810 Method 511.7 where a fuel-vapor or explosive-atmosphere hazard is credible; test configuration must represent heaters, switches and fault controls.	Method 511.7 for fuel-handling, engine-bay or munitions-related locations where invoked; otherwise document non-applicability.
Material outgassing	Normally a program/installation cleanliness, odor, fogging or contamination requirement rather than a universal DO-160 test. Identify volatile/condensable limits and optical witness method when needed.	Program-specific for sealed optics, sensors, high-altitude compartments and contamination-sensitive equipment. ASTM E595 may be used as screening only when contractually invoked.	Apply to sealed shelters/displays, vacuum or sensor-adjacent installations and high-temperature enclosures where contamination/fogging is credible.
Pressure/altitude effects on optical bonds	After altitude, decompression, thermal variation and humidity, require no delamination or unacceptable bubble/void growth, haze, Newton rings, edge lift or optical shift. Define limits by viewing zone.	Verify the finished panel/filter/touch/heater/shield/cover stack through the tailored altitude and thermal sequence. Include repair limits and evidence for trapped-gas control and bond-line process capability.	Verify cold/high-altitude and transport profiles, especially for thick cover windows and sealed bezels. Define allowable cosmetic defects separately from functional delamination or readability loss.

- **Supplier flowdown — Material requirements should identify the controlled formulation, supplier, thickness and cured state. Optical-bond acceptance should define inspection lighting/magnification, viewing zones, maximum bubble/void size and count, edge exclusion, haze/reflectance/luminance/color shift, bond-line displacement and delamination criteria before, during and after exposure.**

9.2.7 Test configuration, performance and evidence

Flowdown item	Minimum content passed to display provider	Integrator / authority retention
Requirement identity	Standard and revision; section/method/procedure/category; numeric severity, waveform/profile, axes, duration/cycles and tolerances; installation zone and life-cycle state.	Approve applicability, tailoring, safety allocation and any deviations/equivalencies.
Test article	Controlled delivered part number/revision and full optical/electrical/mechanical stack; production-representative statement; sample quantity and sequence.	Confirm representation of aircraft/vehicle mounting, harness, cooling, grounding and installation interfaces.
Operating configuration	Input power, video patterns, luminance/dimming, backlight, heater, touch, communications, built-in test, cooling and worst-case software/firmware settings.	Identify safety/mission modes, aircraft/vehicle source characteristics and installation-dependent operating states.
Performance criteria	Pre-, during- and post-test functional/optical checks; permitted upset and recovery time; no-hazard/no-damage criteria; luminance, contrast, color, NVIS, touch and bond/seal limits.	Define installed readability, human-factors, safety, nuisance-trip and dispatch/mission consequences.
COTS evidence	OEM data, test reports and limitations; configuration mapping; differences in size, panel lot, backlight, controller and material; similarity/gap analysis and planned delta tests.	Accept or reject credit for similarity and identify installation tests that cannot be delegated.
Enhanced COTS	Qualify the completed modification: high-bright backlight/NVIS filter, touch, heater, transparent shield, optical bond, cover/coating, bezel/frame, controller and firmware. Do not claim untouched-panel qualification as finished-stack qualification.	Approve modification baseline, critical processes, manufacturing site, acceptance tests and requalification triggers.
Evidence package	Approved plan/procedure; photos and setup diagrams; calibrated data; anomalies; raw/processed optical results; pass/fail matrix; configuration list; report; deviations; corrective action and residual limitations.	Close compliance findings and link reports to system verification, installation approval and continued-airworthiness/configuration records.

Primary sources: FAA AC 21-16G; EASA recognition of ED-14G/DO-160G technical equivalence; EASA AMC 20-158A; MIL-STD-810H Change 1; MIL-STD-461H; MIL-STD-464D; MIL-STD-704F; and MIL-STD-1275F [R29]–[R34], [R51]–[R54]. Method numbers and representative values above must be confirmed against the controlled project revisions and approved tailoring.

9.3 Supplier verification documentation

- Requirements compliance matrix with method, procedure, report number, configuration and exceptions.
- Qualification test plan and report, including pre/post functional and optical limits.
- Acceptance test procedure and serialized or lot-level results.
- Optical measurement report with equipment, calibration, geometry, uncertainty, stabilization and ambient controls.
- NVIS report including spectral data and exact configuration of all spectrum-affecting components.
- Environmental and EMI test reports tied to drawings, BOM, firmware and test-unit serial numbers.
- Material and process specifications for bonding, cleaning, coating, heater, shield, sealing and repair.
- Reliability, life, FMEA/FMECA and failure-behavior evidence appropriate to the allocated criticality.
- Certificates, source inspection, first-article evidence and nonconformance/deviation records.
- Supplier quality-management certification status and scope, including AS9100D/EN 9100 when contractually required, certified sites and activities, certification-body and certificate validity, and OASIS status when applicable.

10. Configuration, lifecycle and change control

COTS and enhanced-COTS displays create certification and military-airworthiness risk when the commercial manufacturer changes the design without preserving form, fit, function or optical equivalence. The controlled configuration should extend below the supplier top-level part number whenever a change can affect approved performance.

10.1 Configuration items requiring control

Configuration group	Examples
Display engine	Panel manufacturer/model, cell process, pixel structure, timing controller, driver IC, OLED/MicroLED compensation and calibration data.
Illumination	LED manufacturer/type/bin, phosphor, optical films, light guide, reflector, drive electronics, PWM frequency and thermal interface.
Optical stack	Polarizers, NVIS filters, touch sensor, cover, bond material/thickness, AR/HEA, ITO, hot mirror, mesh, hard coat and layer order.
Mechanical/thermal	Frame, bezel, fasteners, gaskets, heat spreaders, fans, heat sinks, adhesives and grounding/bonding provisions.
Electronics/software	PCB assembly, FPGA/CPLD, firmware, bootloader, video processing, calibration, communication protocol and programmable settings.
Manufacturing	Factory/site, key processes, tooling, inspection standards, test software, repair/rework method and approved sub-tier suppliers.

10.2 Change-notification requirements

- Advance product-change notification with affected part numbers, reason, implementation date and last-time-buy dates.
- Delta description identifying changes to design, material, process, firmware, manufacturing site, sub-tier supplier or test method.
- Supplier impact assessment against every approved requirement and qualification report.
- Proposed verification/requalification plan and side-by-side optical, electrical, environmental, NVIS and EMC evidence where relevant.
- No shipment of changed configuration until written approval when the product supports an approved or safety-significant installation.

10.3 Obsolescence and long-term support

- Define required production/support life, annual demand range, minimum order quantities, storage life and repair period.

- Identify tooling, masks, calibration equipment, source code/firmware and technical-data ownership or escrow needs.
- Plan last-time buys, lifetime buys, storage controls, periodic retest and alternate-source qualification.
- For custom LCD/OLED/MicroLED, control foundry/fab, process node, mask revision, materials and yield/defect criteria.
- For enhanced COTS, ensure the value-added provider can detect OEM changes rather than relying only on the unchanged commercial part number.

Appendix A. Current standards snapshot

This planning snapshot is current to 16 August 2026. Always verify the project certification basis, controlled standard revisions, authority acceptance, transition dates and contract invocation before use.

Domain	Document/revision	Status/use note
U.S. civil display	14 CFR Parts 23, 25, 27, 29; AC 25-11B	Binding regulations plus nonmandatory FAA guidance.
Display article	TSO/ETSO-C113b; SAE AS8034C	Multipurpose electronic display; separate installation approval required.
Aerospace quality management	AS9100D / EN 9100:2018 (IAQG 9100:2016; ISO 9001:2015 baseline)	Organizational QMS standard; apply when contractually required or within the certification scope. It does not replace product airworthiness, design or production approvals. Confirm any IA9100-series transition before use.
Civil environment	DO-160G / ED-14G	Select categories based on installation.
Civil software/hardware	DO-178C / ED-12C; DO-254 / ED-80	Assurance level allocated from system safety.
U.S. military airworthiness	MIL-HDBK-516D, May 2026	Criteria selected/tailored by service authority.
Military NVIS	MIL-STD-3009, Notice 2 validation 2024	Aircraft lighting/display emission compatibility.
Military human factors	MIL-STD-1472H, Notice 1, April 2026	Tailored human engineering.
Military environment	MIL-STD-810H Change 1	Tailored test methods; no universal fixed severity.
Military EMI	MIL-STD-461H, April 2026	Equipment-level requirements; confirm transition from 461G.
Military E3	MIL-STD-464D, Notice 1, February 2026	Platform/system electromagnetic effects.
Aircraft power	MIL-STD-704F, Notice 4, June 2026	Aircraft power characteristics.
Ground vehicle power	MIL-STD-1275F	28 VDC military vehicle power.
Optical surface	MIL-PRF-13830B; ISO 10110-7:2017	Different systems; do not convert without agreement.
Surface test	ISO 14997:2017; ISO/TR 14997-2:2022	Visual/visibility test methods and machine-vision guidance.
Optical coatings	ISO 9211-2:2024; -3:2024; -4:2022; -5:2018	Optical properties, durability, tests and AR minimums.

Appendix B. Supplier data-item checklist

Use this checklist to define contractual data deliverables and acceptance evidence for each supplier. Tailor it by safety allocation, installation, product maturity, acquisition category and certification basis; identify the required revision, format, approval status and delivery milestone in the purchase specification or data-item list.

- ☐ Approved product specification and outline/interface drawing
- ☐ Controlled top-level BOM and identification of critical sub-tier sources
- ☐ Supplier QMS certification and scope, including AS9100D/EN 9100 and OASIS status when contractually required
- ☐ Interface control document and video/power timing definition
- ☐ Optical performance specification and complete measurement procedure
- ☐ NVIS specification, test procedure and spectroradiometric report
- ☐ Cover-window, bonding, coating, heater and EMI-shield material/process specifications
- ☐ Surface quality and cosmetic inspection specification, including zones and inspection method
- ☐ Environmental design criteria and installation-zone declaration, including supplier versus integrator closure responsibility
- ☐ COTS/enhanced-COTS configuration mapping, similarity or gap analysis, and delta-qualification rationale
- ☐ Environmental test configuration matrix, sequence rationale, anomalies and pre/during/post functional and optical results
- ☐ Environmental qualification matrix, plan and report
- ☐ EMI/EMC test plan and report
- ☐ Software/firmware and programmable-hardware configuration and assurance data as allocated
- ☐ FMEA/FMECA, failure behavior, reliability and life data
- ☐ Qualification test units and production-representativeness statement
- ☐ Acceptance test procedure and production test record format
- ☐ Calibration requirements and measurement uncertainty budget
- ☐ First article inspection and source-inspection evidence
- ☐ Certificates of conformance and special-process certifications
- ☐ Deviation, waiver and nonconformance control procedure
- ☐ Product-change notification and requalification procedure
- ☐ Obsolescence, last-time-buy and long-term-support plan
- ☐ Instructions for installation, maintenance, cleaning, repair and continued airworthiness

Appendix C. Glossary and abbreviations

Term	Meaning
COTS	Commercial off-the-shelf.
Enhanced COTS	A commercial display modified by a value-added provider with controlled optical, electrical, thermal or mechanical enhancements.
DAL	Development Assurance Level.
E3	Electromagnetic environmental effects.
EMI/RFI	Electromagnetic/radio-frequency interference.
ETSO/TSO	European/U.S. Technical Standard Order article approval.
HEA/AR	High-efficiency antireflection/antireflective optical coating; performance must be defined spectrally and geometrically.
HIRF	High-intensity radiated fields.
ICA	Instructions for Continued Airworthiness.
ITO	Indium tin oxide, a transparent conductive material used for heaters and/or EMI shielding.
Mura	Spatial nonuniformity visible as patches, bands or other nonuniform image structure.
NVG	Night vision goggles.
NVIS	Night Vision Imaging System, including NVGs and the compatible lighting/display environment.
PCN	Product Change Notification.
STC	Supplemental Type Certificate.
TC	Type Certificate.

Appendix D. Colabmo and FPD.DEV client support services

Colabmo supports product teams from early concept through market entry and lifecycle change. Engagements may be advisory, embedded within the client team, or organized as a defined work package. FPD.DEV, Colabmo's sister company, extends this support with specialized flat-panel display, optical, touch, electronics, supplier-development, and manufacturing capabilities.

> **Role boundary.** Colabmo and FPD.DEV do not issue regulatory approvals, certifications, or marks. They support the manufacturer or applicant in preparing evidence and coordinating with regulators, accredited laboratories, Nationally Recognized Testing Laboratories (NRTLs), certification bodies, and EU Notified Bodies, as applicable. The manufacturer retains responsibility for regulatory strategy, declarations, product conformity, and use of marks.

D.1 Product development and requirements

- Clarify intended use, users, operating environments, system boundaries, interfaces, and measurable acceptance criteria.
- Translate stakeholder and regulatory needs into requirements baselines, traceability, interface controls, supplier flowdowns, and verification plans.
- Facilitate architecture and design reviews, risk-based trade studies, design-for-compliance decisions, and evidence-focused readiness reviews.
- Support configuration control, supplier change assessment, obsolescence planning, prototype maturation, and transfer to repeatable production.
- Integrate display selection and customization, optical performance, sunlight readability, NVIS/NVG compatibility, EMI/RFI control, heaters, bonding, cover windows, backlights, interfaces, and environmental qualification into the system baseline.

D.2 Regulatory navigation and evidence readiness

- Develop a market-entry roadmap covering product classification, approval or conformity-assessment routes, authorities and bodies, program gates, and decision owners.
- Build and maintain standards-applicability, revision, recognition or harmonisation, and transition matrices tailored to the product and target markets.
- Perform evidence-gap assessments and organize compliance matrices, technical documentation, design-history records, test reports, declarations, and supplier evidence.
- Plan pre-compliance and formal testing, review submission or certification packages, and help teams prepare clear responses to reviewer questions and nonconformities.

D.3 Certification and conformity-assessment coordination

- Prepare organizations for AS9100D/EN 9100 certification through QMS gap assessments, process and documentation review, objective-evidence sampling, internal pre-audit readiness reviews, and certification-body engagement planning.
- Provide post-audit QMS support for containment, root-cause analysis, corrective-action plans, implementation and effectiveness evidence, and closure of audit findings.
- Help identify and coordinate the appropriate regulator, accredited laboratory, UL or other NRTL route, certification body, and EU Notified Body when required by the product and market.
- Develop test scopes, evidence matrices, sample and configuration definitions, submission schedules, and responsibility assignments before formal engagement.
- Coordinate technical exchanges, test witnessing, findings, corrective actions, retesting, and closure records with the selected bodies and laboratories.
- Support readiness for UL certification and mark authorization, and for CE marking through the applicable EU conformity-assessment route, including declaration, labeling, and technical-file checks.

D.4 Sister-company support through FPD.DEV

- Provide display-platform and component selection, custom display and electronics development, optical-stack and touch integration, backlight solutions, ruggedization, prototyping, and supplier development.
- Coordinate display-specific requirements and evidence with the broader Colabmo regulatory, systems-engineering, quality, and certification workstream.
- Support sourcing, manufacturer engagement, first-article and pilot-build readiness, production transfer, and lifecycle continuity for display-intensive products.
- Define ownership, milestones, interfaces, deliverables, assumptions, and acceptance criteria for each Colabmo and FPD.DEV engagement in the client statement of work.

References

Sources are authoritative regulatory, standards-body or testing/certification references. Standard names and scopes are referenced for planning; this document does not reproduce copyrighted standard text.

ID	Authority	Source	URL
R1	eCFR / CFR	14 CFR Part 25, Subpart F	https://www.ecfr.gov/current/title-14/chapter-I/subchapter-C/part-25/subpart-F
R2	eCFR / CFR	14 CFR Part 23	https://www.ecfr.gov/current/title-14/chapter-I/subchapter-C/part-23
R3	eCFR / CFR	14 CFR Part 27, Subpart F	https://www.ecfr.gov/current/title-14/chapter-I/subchapter-C/part-27/subpart-F
R4	eCFR / CFR	14 CFR Part 29, Subpart F	https://www.ecfr.gov/current/title-14/chapter-I/subchapter-C/part-29/subpart-F
R5	FAA	FAA Advisory Circular index, including AC 25-11B and AC 23.1311-1C	https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.list/parenttopicid/11
R6	FAA	FAA TSO-C113b, Airborne Multipurpose Electronic Displays	https://drs.faa.gov/browse/excelExternalWindow/70A15EDCBD2A6ECE8625830D0049B58F.0001
R7	FAA	FAA Technical Standard Orders overview	https://www.faa.gov/aircraft/air_cert/design_approvals/tso
R8	FAA	FAA Human Factors and TSOs	https://www.faa.gov/aircraft/air_cert/design_approvals/dah/human_factors
R9	FAA	FAA AC 20-115D, DO-178C recognition	https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1032046
R10	FAA	FAA AC 20-152A, DO-254/ED-80 recognition	https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1041323
R11	FAA	FAA AC 20-174, ARP4754A recognition	https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentID/1019527
R12	FAA / Federal Register	FAA proposed equipment/system information-security rule	https://www.federalregister.gov/documents/2024/08/21/2024-17916/equipment-systems-and-network-information-security-protection
R13	EASA	EASA CS-23 Amendment 6	https://www.easa.europa.eu/en/document-library/certification-specifications/cs-23-amendment-6-and-amc-gm-cs-23-issue-5
R14	EASA	EASA CS-25 Amendment 28	https://www.easa.europa.eu/en/document-library/certification-specifications/cs-25-amendment-28
R15	EASA	EASA CS-27 Amendment 10	https://www.easa.europa.eu/en/document-library/certification-specifications/cs-27-amendment-10
R16	EASA	EASA CS-29 Amendment 12	https://www.easa.europa.eu/en/document-library/certification-specifications/cs-29-amendment-12
R17	EASA	EASA list of all ETSOs	https://www.easa.europa.eu/en/domains/aircraft-products/etso/list-of-all-etso

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R18	EASA	EASA ETSO-C113b	https://www.easa.europa.eu/download/etso/ETSO-C113b.pdf
R19	EASA	EASA AMC 20-115D	https://www.easa.europa.eu/en/document-library/easy-access-rules/online-publications/easy-access-rules-acceptable-means?page=22
R20	EASA	EASA AMC 20-42	https://www.easa.europa.eu/en/document-library/easy-access-rules/online-publications/easy-access-rules-acceptable-means?page=21
R21	FAA	FAA NVIS certification policy and checklists	https://www.faa.gov/aircraft/air_cert/design_approvals/rotorcraft/nvis
R22	EASA	EASA Easy Access Rules for Air Operations	https://www.easa.europa.eu/en/document-library/easy-access-rules/online-publications/easy-access-rules-air-operations
R23	EASA	EASA CM-FT-001, Night Vision Imaging Systems	https://www.easa.europa.eu/en/document-library/product-certification-consultations/cm-ft-001
R24	U.S. DoD / DLA	MIL-HDBK-516D	https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=212162
R25	U.S. DoD / DLA	MIL-STD-3009	https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=209352
R26	U.S. DoD / DLA	MIL-L-85762A	https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=35030
R27	U.S. DoD / DLA	MIL-STD-1787D	https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=37143
R28	U.S. DoD / DLA	MIL-STD-1472H	https://quicksearch.dla.mil/qsdocdetails.aspx?ident_number=36903
R29	U.S. DoD / DLA	MIL-STD-810H	https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=35978
R30	U.S. DoD / DLA	MIL-STD-461H	https://quicksearch.dla.mil/qsdocdetails.aspx?ident_number=35789
R31	U.S. DoD / DLA	MIL-STD-464D	https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=35794
R32	U.S. DoD / DLA	MIL-STD-704F	https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=35901
R33	European Defence Agency	European Defence Agency MAWA documents	https://eda.europa.eu/experts/airworthiness/mawa-documents
R34	U.S. DoD / DLA	MIL-STD-1275F	https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=36186
R35	NATO	NATO Generic Vehicle Architecture/STANAG 4754 technical publication	https://publications.sto.nato.int/publications/STO%20Meeting%20Proceedings/STO-MP-IST-209/MP-IST-209-1755.pdf
R36	eCFR / CFR	FMVSS 101	https://www.ecfr.gov/current/title-49/subtitle-B/chapter-V/part-571/subpart-B/section-571.101

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R37	eCFR / CFR	FMVSS 111	https://www.ecfr.gov/current/title-49/subtitle-B/chapter-V/part-571/subpart-B/section-571.111
R38	EUR-Lex	EU Regulation 2019/2144	https://eur-lex.europa.eu/eli/reg/2019/2144/oj/eng
R39	UNECE	UNECE vehicle regulations, including Regulation No. 10	https://unece.org/transport/vehicle-regulations-wp29/standards/addenda-1958-agreement-regulations-0-20
R40	SAE	SAE ARP4260, airborne display measurement procedures	https://www.sae.org/standards/arp4260-photometric-colorimetric-measurement-procedures-airborne-flat-panel-displays
R41	SAE	SAE ARP4256A, LCD design objectives for Part 25 aircraft	https://saemobilus.sae.org/standards/arp4256a-design-objectives-liquid-crystal-displays-part-25-transport-aircraft
R42	IEC	IEC 61747-1-1:2014, LCD generic specification	https://webstore.iec.ch/en/publication/5750
R43	ISO	ISO 9211-2:2024, Optical coatings - Optical properties	https://www.iso.org/ics/37.020.html
R44	ISO	ISO 9211-3:2024, Optical coatings - Environmental durability	https://www.iso.org/ics/37.020.html
R45	ISO	ISO 9211-4:2022, Optical coatings - Specific test methods	https://www.iso.org/ics/37.020.html
R46	ISO	ISO 9211-5:2018, Minimum requirements for antireflecting coatings	https://www.iso.org/ics/37.020.html
R47	U.S. DoD / DLA	MIL-PRF-13830, active status	https://quicksearch.dla.mil/qsDocDetails.aspx?ident_number=10290
R48	ISO	ISO 10110-7:2017, surface imperfections	https://www.iso.org/standard/65444.html
R49	ISO	ISO 14997:2017, surface-imperfection test methods	https://www.iso.org/standard/63464.html
R50	ISO	ISO/TR 14997-2:2022, machine vision	https://www.iso.org/ics/37.020.html
R51	FAA	FAA AC 21-16G, RTCA Document DO-160 versions and environmental qualification guidance	https://www.faa.gov/regulations_policies/advisory_circulars/index.cfm/go/document.information/documentid/1019280
R52	EASA	EASA AMC material recognizing EUROCAE ED-14G as technically equivalent to RTCA DO-160G	https://www.easa.europa.eu/en/document-library/easy-access-rules/online-publications/easy-access-rules-acceptable-means-0?page=26
R53	EASA	EASA AMC 20-158A, aircraft electrical and electronic system HIRF certification	https://www.easa.europa.eu/sites/default/files/dfu/annex_iii_to_ed_decision_2022-001-r_amc_20-158a_aircraft_electrical_and_electronic_system_high-intensity_radiated_fields_hirf.pdf
R54	EASA	EASA AMC 20-136A, aircraft electrical and electronic system lightning protection	https://www.easa.europa.eu/en/document-library/easy-access-rules/online-publications/easy-access-rules-acceptable-means-2?page=24
R55	IAQG	IAQG 9100 Quality Management Systems requirements for aviation, space and defense organizations	https://iaqg.org/standard/9100-qms-requirements-for-aviation-space-and-defense-organizations/

Revision control reminder
Standards and regulations change. Confirm the current controlled revision, amendments, notices, authority acceptance and contract invocation before placing requirements on a drawing, purchase order or compliance matrix.