# DO-160 Display Qualification

Introduction

CHAPTER 1

## In this chapter

Display capability and qualification evidence

Measurable acceptance criteria

The complete assembly and its installation



**Diggy Breiling**
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**Current: CMDA**
Previously held: CSSBB, CMQ/OE
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Association for Supply Chain Management

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LCDs since 1992
Optical lab work since 1994

# Course scope and intended outcome



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## Components, systems and installation

Display engineering with Diggy

# Enhancing a COTS display

01 Temperature range and durability

02 Contrast, brightness and spectral performance

03 Touch capabilities and application interfaces

04 Verify the enhanced assembly and its limits

# The qualification plan you will build

01 An identified display and installation

02 A matrix of requirements and evidence

03 A procedure, monitoring plan and handover

# The running qualification matrix

| Requirement | Method / category | Evidence state |
| --- | --- | --- |
| Cold image performance | Section 4; allocation open | Planned; integrator input needed |
| Vibration, new bracket | Section 8; method open | Earlier report; credit unresolved |
| External exposure | Document applicability rationale | No result inferred from blank cells |

**Applicability and evidence status stay separate / Unknown inputs have a named owner / Each chapter adds to the same record**

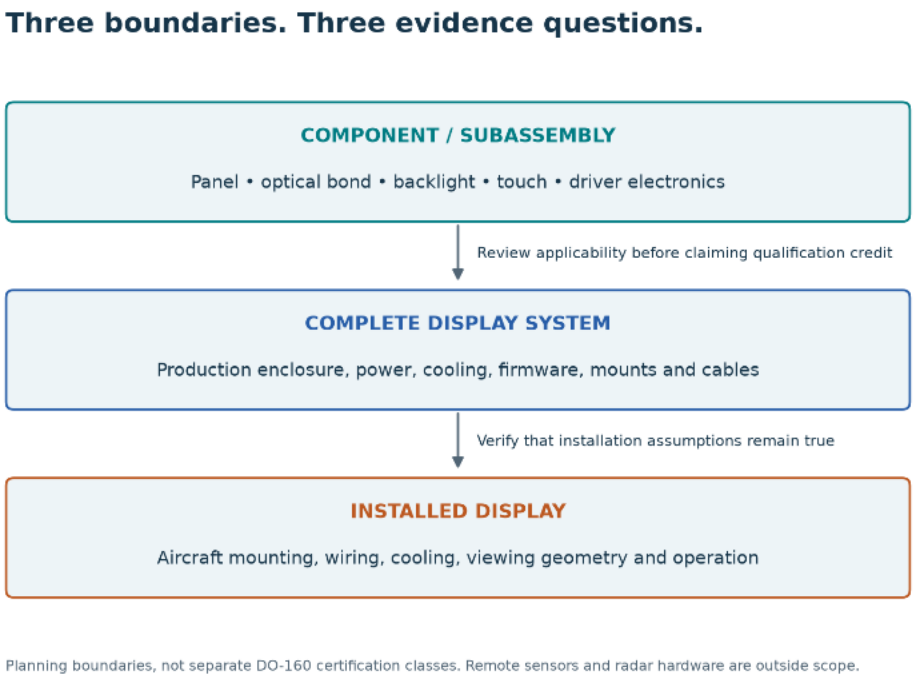
# References and further study

01 DO-160 / ED-14 and adopted changes

02 Military, display and assurance requirements

03 Edition, applicability and evidence references

# Component, system and installed display




**Component capability has a defined boundary**

The complete assembly carries the interfaces

Installation preserves the tested assumptions

FPD.DEV original teaching graphic; A-P02

# What a qualification claim needs

01 Edition and category

02 As-tested configuration and reports

03 Performance results and installation limits

# Panel evidence has a defined boundary

## TESTED COMPONENT




**Panel report**

Part / mode / profile
Measured results

**Match the evidence to the panel requirement**

→

## ADDED IN YOUR PRODUCT

- Bonded glass
- Touch electronics
- Power conversion
- Housing
- Mount
- Interfaces

**Assess the complete assembly**

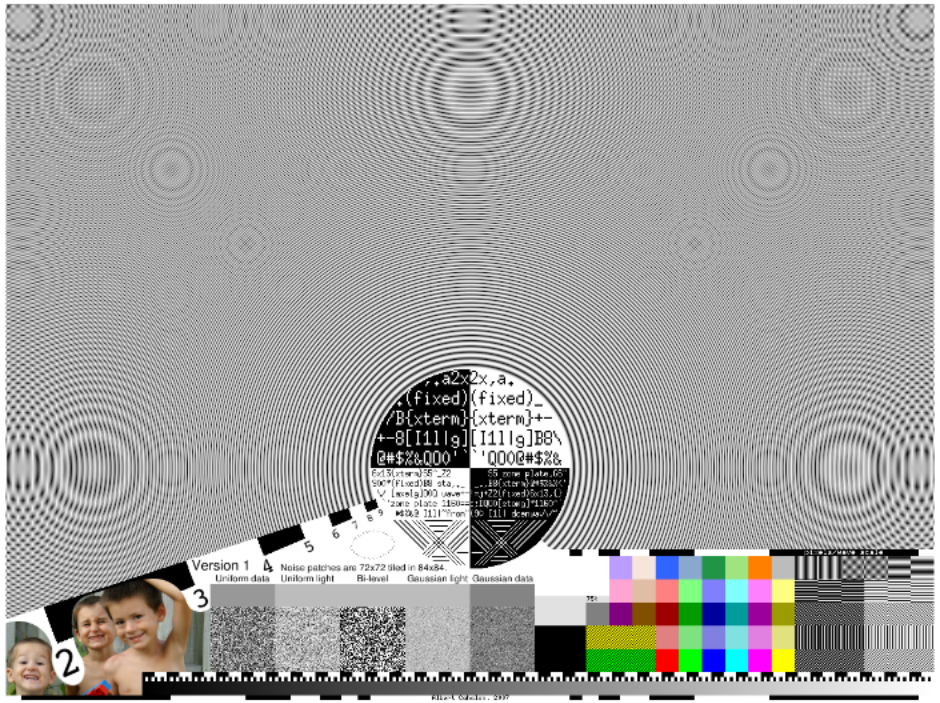
**A panel report supports a defined scope of evidence.**

# Turn the report into an evidence plan

| Record | What to establish |
| --- | --- |
| Supported scope | Panel requirement matched to report conditions |
| Open inputs | Missing configuration, results or installation data |
| Remaining verification | Added functions, interfaces and assembly behavior |

**Keep supported credit, open inputs and remaining work visible**

# Acceptance criteria come first




**A lit screen can still show stale information**

Image, controls and validity need monitoring

During, after and survival are separate states

AlbertCahalan (Wikimedia Commons: AlbertCahalan~commonswiki); CC BY-SA 3.0

# A measurable acceptance record

| Function | Teaching criterion | Required measurement context |
| --- | --- | --- |
| Cold startup | Usable image within 60 s | Initial soak, valid input, power threshold |
| Hot Contrast | Ambient contrast at least 5:1 | Panel +70 C; 50,000 lx; stated geometry |

**Illustrative values only; program requirements control**

# Hot Contrast in bright ambient light

01 Hot Contrast: contrast at a stated display temperature

02 Bright ambient light falls onto the screen

03 Record lux, reflection geometry and viewing direction

04 Heat and reflected light can both reduce contrast

# Worked example: capture the transient

01 Use a changing image and log control outputs

02 Synchronize events with the applied exposure

03 Judge duration and recovery against agreed criteria

# The environmental coverage map

| Family | DO-160G sections |
| --- | --- |
| Temperature, pressure, moisture, mechanical | 4–8, 10–14 |
| Magnetic, power, induced signals and RF | 15–21 |
| Lightning and human-accessible ESD | 22, 23, 25 |
| Explosion proofness, icing, fire | 9, 24, 26 |

**Climatic and mechanical exposures / Electrical and electromagnetic effects / Installation-specific hazards**

# DO-160 and MIL-STD-810

01 DO-160: airborne categories and procedures

02 MIL-STD-810: life-cycle tailoring and methods

03 Each invoked requirement needs traceable evidence

# Related subjects, separate procedures

| Subject | DO-160G | MIL-STD-810 family |
| --- | --- | --- |
| Temperature | Section 4 | Methods 501 / 502 |
| Vibration | Section 8 | Method 514 |
| Humidity / salt | Sections 6 / 14 | Methods 507 / 509 |

**Subject mapping guides the comparison**

# Qualification credit across standards

01 Purpose, configuration and operating state

02 Complete profile, duration and sequence

03 Monitoring, acceptance and unresolved gaps



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# The Future of Display and Systems Development

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## Next chapter

### Temperature and Pressure

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# DO-160 Display Qualification

Temperature and Pressure

CHAPTER 2

## In this chapter

Hot Contrast and cold moving information

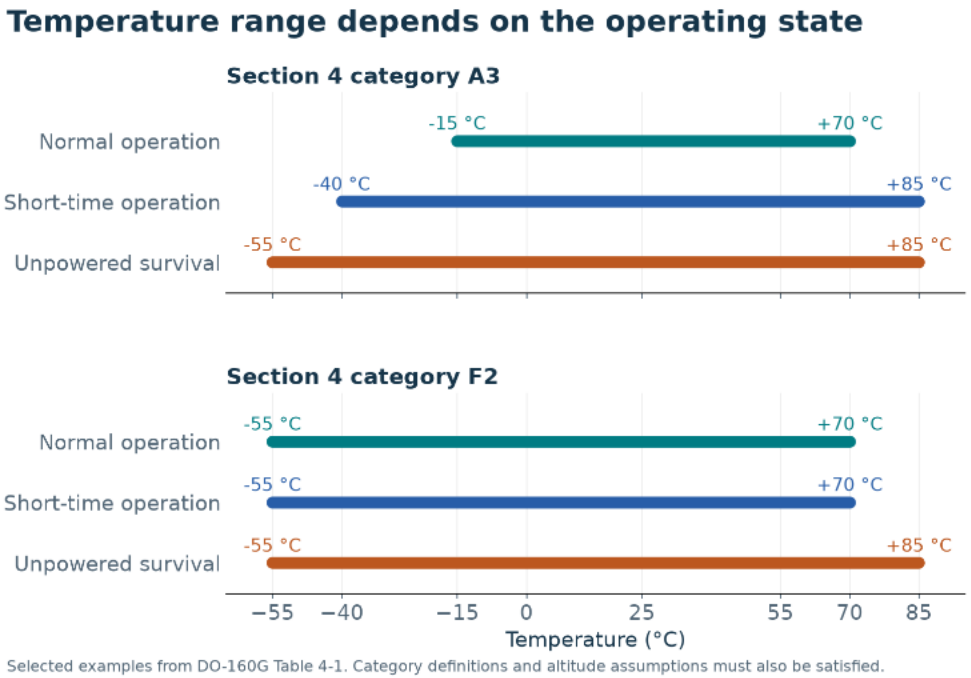
Thermal lag, material response and test sequence

Pressure loads, decompression and venting



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# Operating state gives a limit meaning




**Normal operation**

Short-time operation

Unpowered ground survival

FPD.DEV original teaching graphic; A-P02

# Reading Table 4-1

| Environmental Tests | A | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Operating Low Temp.<br>Degrees C<br>Paragraph 4.5.2 | -15 | -15 | -15 |
| Operating High Temp.<br>Degrees C<br>Paragraph 4.5.4 | +55 | +70 | +70 |
| Short-Time Operating Low Temp.<br>Degrees C<br>Paragraph 4.5.1 | -40 | -40 | -40 |
| Short-Time Operating High Temp.<br>Degrees C<br>Paragraph 4.53 | +70 | +70 | +85 |

**A3 operating low: −15 °C**

A3 short-time operating low: −40 °C

The category definition still governs

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# Cold response and moving information

01 Cold increases LC viscosity and slows optical switching

02 Moving dials, indicators and maps can smear

03 Check dynamic readability during cold start and operation

# CTE: what changes, and by how much?

$$\Delta L \approx \alpha L_0 \Delta T$$

### α · Material CTE

Fractional length change per degree

### $L_0$ · Initial length

The length being evaluated

### ΔT · Temperature change

Final temperature minus initial temperature

### CTE: ppm/K or ppm/°C · 1 ppm = $10^{-6}$

Use approximately constant CTE only over an appropriate temperature interval.

# Worked example: 0.120 mm of mismatch

**CTE difference**

$23 - 8 = 15$ ppm/K

**Distance from constraint**

$L = 100$ mm

**Temperature change**

$\Delta T = 80$ K

$$\Delta u \approx 15 \times 10^{-6}/\mathrm{K} \times 100\ \mathrm{mm} \times 80\ \mathrm{K}$$

## 0.120 mm

**Relative free movement from the center constraint to the edge**

Teaching inputs, not material specifications. Bonded layers cannot freely move this amount.

# Stiffness, force and movement

## Same imposed movement

Both joints stretch equally. Reaction force differs.

**k = 10 N/mm**



u = 1.0 mm  **F = 10 N**

**k = 40 N/mm**



u = 1.0 mm  **F = 40 N**

## Same applied force

The more compliant joint moves farther.

**k = 10 N/mm**



**u = 1.00 mm**  **F = 10 N**

**k = 40 N/mm**



**u = 0.25 mm**  **F = 10 N**

**F = k u**  **Assembly stiffness k depends on material AND geometry.**

Axial bar: k = E A / L.  Material modulus E differs from joint stiffness k.

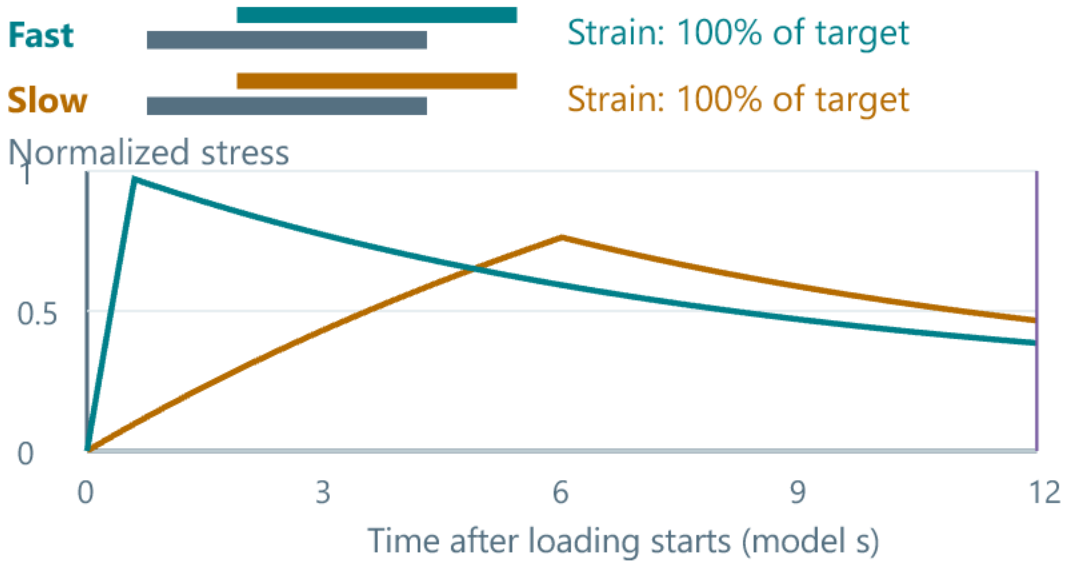
Illustrative linear springs; equal geometry in this comparison. Softer is not automatically better.

# Temperature and loading rate

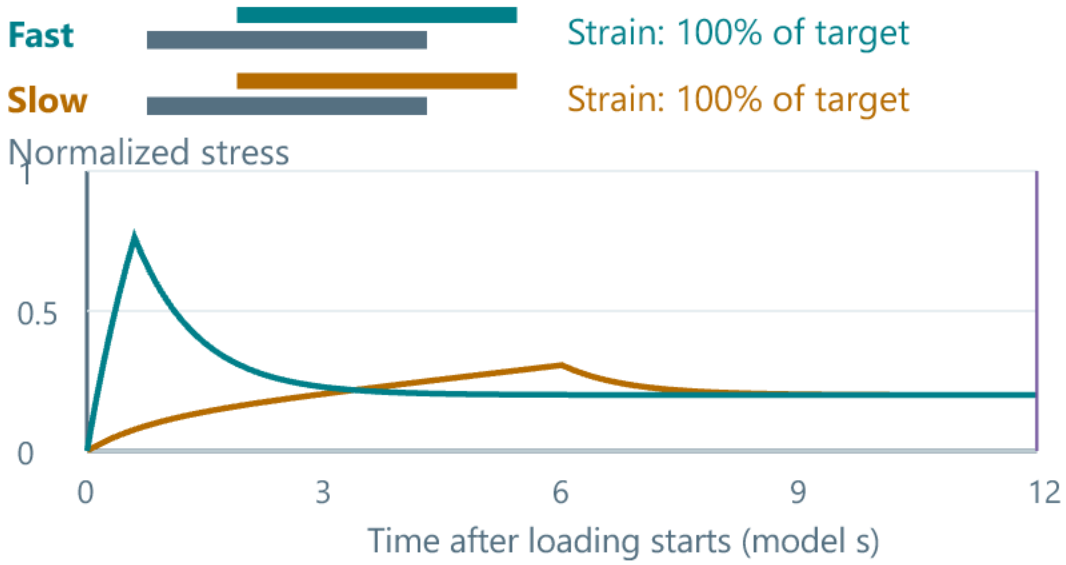
## Same final strain. Different ramp times and relaxation times.

Model time: 12.0 s  Fast ramp: 0.6 s  Slow ramp: 6 s  Then hold the strain.

### COOLER example: slower relaxation




### WARMER example: faster relaxation



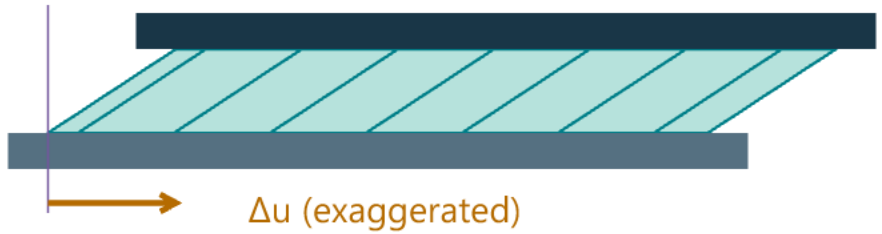

Illustrative viscoelastic model, not material data. Mechanical strain rate differs from chamber °C/min.

# Bond thickness and shear strain

## Same relative movement across two bond thicknesses

Relative displacement Δu = 0.050 mm  Assumed shear modulus G = 0.20 MPa

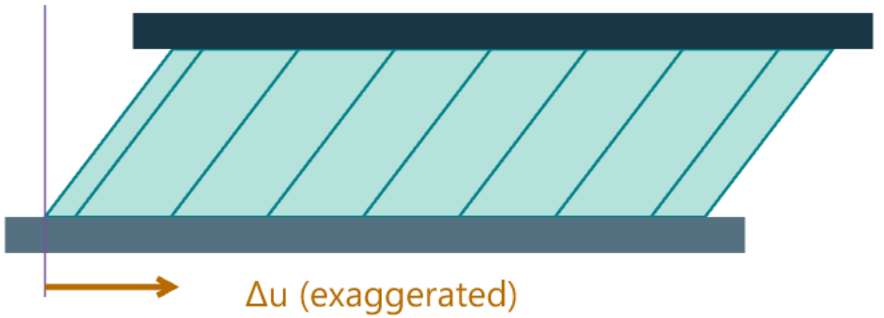
### Bond thickness t = 0.5 mm




**Shear strain γ = Δu / t = 10.0%**

Elastic stress τ = G γ = 20.0 kPa

### Bond thickness t = 1.0 mm




**Shear strain γ = Δu / t = 5.0%**

Elastic stress τ = G γ = 10.0 kPa

**Half the thickness doubles strain for the same imposed displacement.**

Temperature and loading rate change the effective modulus and stress history.

Uniform simple-shear example only. Edge peel, creep, strength and optical performance need separate checks.

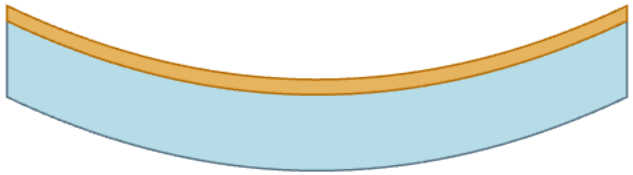
# Laminate mismatch and restraint

## Film shrinks relative to glass

Bonded mismatch creates stress. Amber: film. Blue: glass. Positive stress: tension.

### Free asymmetric laminate

Film free mismatch: -0.50%



**Bending + internal stress**

Mean front-film stress: 14.3 MPa

Longer layer lies outside the curve.

### Balanced front and rear films

Film free mismatch: -0.50%



**Little bow; internal stress remains**

Mean front-film stress: 14.7 MPa

Symmetry cancels bending coupling.

### Held flat by a support

Film free mismatch: -0.50%



**Support resists bending**

Mean front-film stress: 14.9 MPa

Reaction moment is nonzero.

Bimetal analogy. LCD films can shrink, relax and respond differently along each direction.

Assumed elastic layers; bow exaggerated. Not a prediction of LCD curvature, mura or a safe temperature.

# A display has several temperatures

01 Chamber air and the LCD cell can differ

02 Measure the panel, backlight and electronics

03 Heater and sunlight create local hot spots

04 Define the location behind each temperature limit

# Hot Contrast: a worked comparison

| Illustrative state | White / black (cd/m²) | Ambient contrast |
|---|---|---|
| Before enhancement | 800 / 200 | 4:1 |
| After enhancement | 720 / 120 | 6:1 |

**Illustrative: 70 °C panel, 50,000 lux at the display**

# Cold motion and heater control

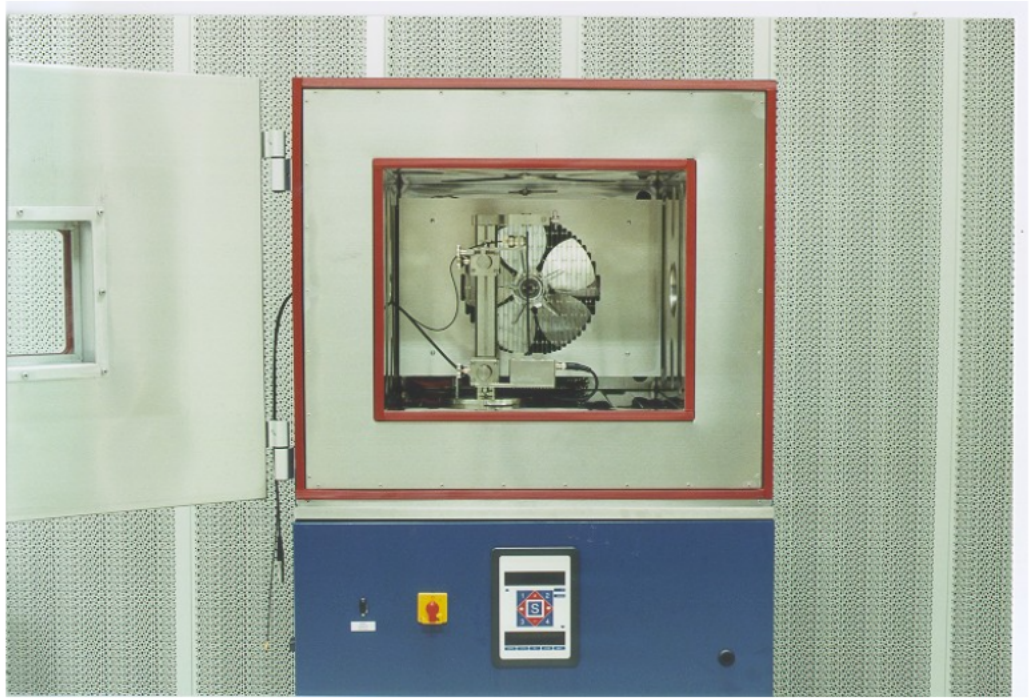
01 Test scrolling maps and moving indicators

02 Measure response at the actual LCD temperature

03 Separate warm-up time from continuous operation

04 Check heater faults and local temperature gradients

# A temperature procedure has stages



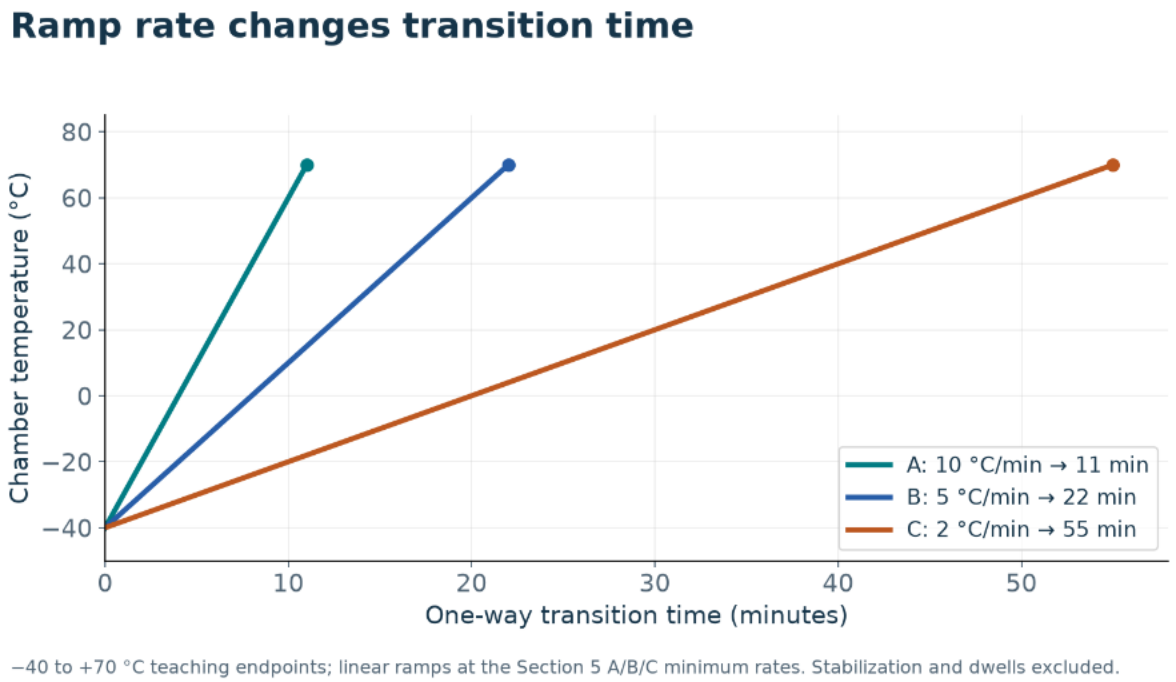
Cjp24; CC BY-SA 3.0

**Conditioning and power state**

Equipment stabilization and timer trigger

Functional checks with recorded temperatures

# Temperature variation and thermal lag



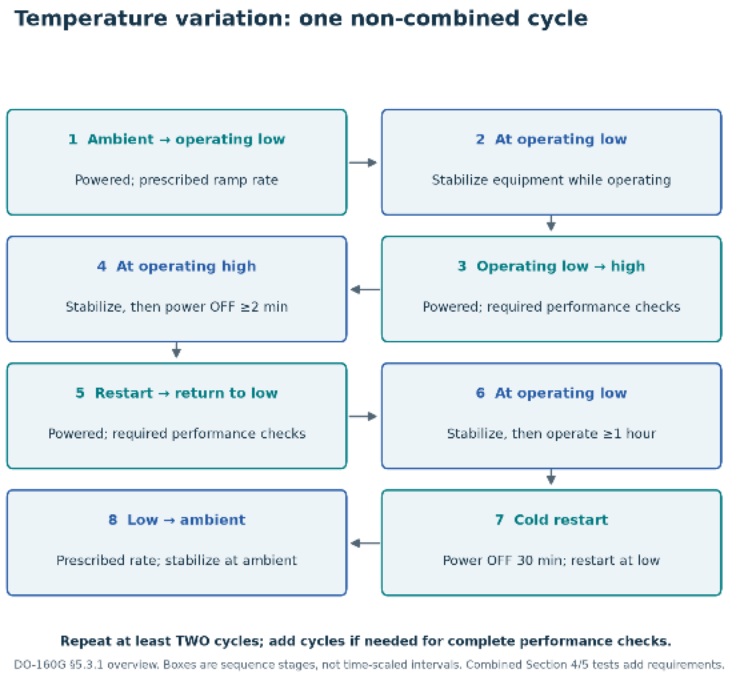

**Section 5 A / B / C: 10 / 5 / 2 °C/min minimum**

110 °C at 5 °C/min takes 22 minutes

Transition time excludes stabilization and dwell

FPD.DEV original teaching graphic; A-P02

# The complete variation sequence




## Powered transitions and restart checks

At least two cycles for A / B / C

Additional checks and full method remain applicable

FPD.DEV original teaching graphic; A-P02

# Thermal lag changes the exposure

01 Air reaches the setpoint before heavy parts

02 Record the gradient across the optical assembly

03 Use the adopted stabilization requirements

04 Preserve the required operating sequence

# Temperature evidence before and after

01 Baseline the optical and functional measurements

02 Monitor critical functions during exposure

03 Repeat measurements after the specified recovery

04 Retain transient faults even if recovery is complete

# Absolute pressure and altitude

| Pressure Altitude | Absolute Pressure | | | |
|---|---|---|---|---|
| | kPa | (mbars) | (in Hg) | mm Hg |
| -15,000 ft (-4,572 m) | 169.73 | 1697.3 | 50.12 | 1273.0 |
| -1,500 ft (-457 m) | 106.94 | 1069.4 | 31.58 | 802.1 |
| 0 ft (0m) | 101.32 | 1013.2 | 29.92 | 760.0 |
| +8,000 ft (+2,438 m) | 75.26 | 752.6 | 22.22 | 564.4 |

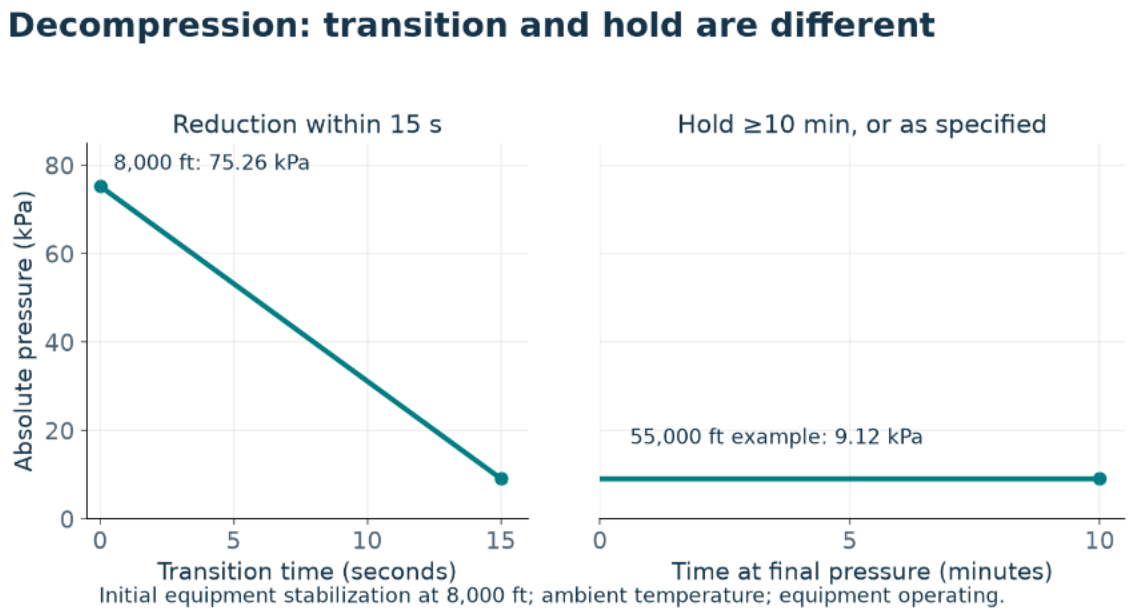
**8,000 ft corresponds to 75.26 kPa absolute**

Gauge pressure needs a reference

Altitude alone does not define the profile

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# Decompression is a pressure transient




DO-160G §4.6.2 / Table 4-2. Illustrative 15 s linear pressure fall; shape is not prescribed. Final altitude is aircraft-specific.

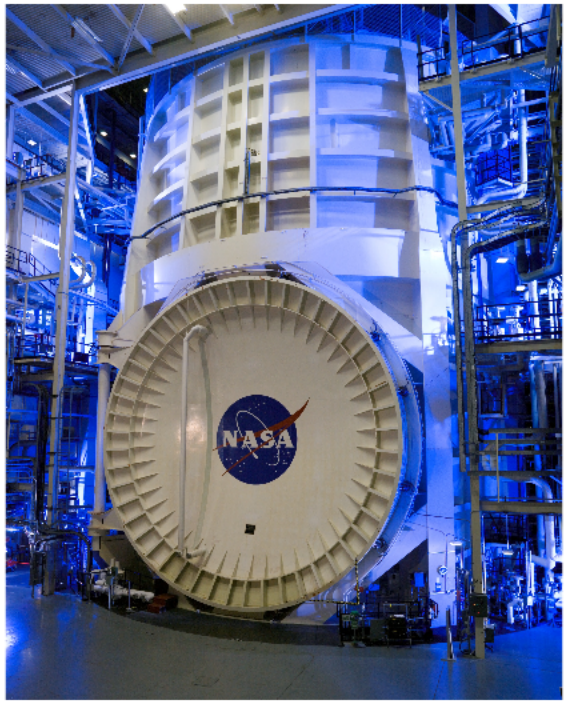
**Initial condition: 8,000 ft equivalent**

Endpoint: aircraft maximum operating altitude

Within 15 s; hold at least 10 min or as specified

FPD.DEV original teaching graphic; A-P02

# Pressure-test equipment




NASA Johnson Space Center; Public domain in the United States

**Vessel, seals and pressure instrumentation**

Pressure profile and powered feedthroughs

Aircraft conditions differ from space vacuum

# Altitude, decompression and trapped air

**01** Restricted equalization creates a pressure difference

**02** Trapped gas can expand or load a constrained cavity

**03** Vents, leakage and decompression rate govern equalization

# Adhesive and cohesive failure

| Failure location | Meaning |
| --- | --- |
| At a bonded interface | Adhesive failure |
| Within adhesive or sealant | Cohesive failure |
| Within film, coating or glass | Identify the damaged layer |

**The fracture location identifies the failure mode**

# Pressure effects across the adhesive system

01 Optical silicones and adhesive films

02 EMI tapes, bonded gaskets and seals

03 Potting and encapsulation compounds

# Pressure difference loads the window

| Quantity | Illustrative value | Meaning |
| --- | --- | --- |
| Window area | 0.200 m × 0.150 m | 0.030 $m^2$ |
| Pressure difference | 20,000 Pa | Internal minus external |
| Resultant force | 20,000 × 0.030 | 600 N |

## Illustrative load before structural analysis

# Vents, seals and pressure monitoring

01 Track internal and external pressure separately

02 Assess vent flow through the installed path

03 Include filters, membranes and blocked-path risks

04 Inspect optical interfaces after recovery



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## Next chapter

### Moisture and Contamination

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# DO-160 Display Qualification

## Moisture and Contamination

CHAPTER 3

## In this chapter

Humidity, water and fluid entry paths

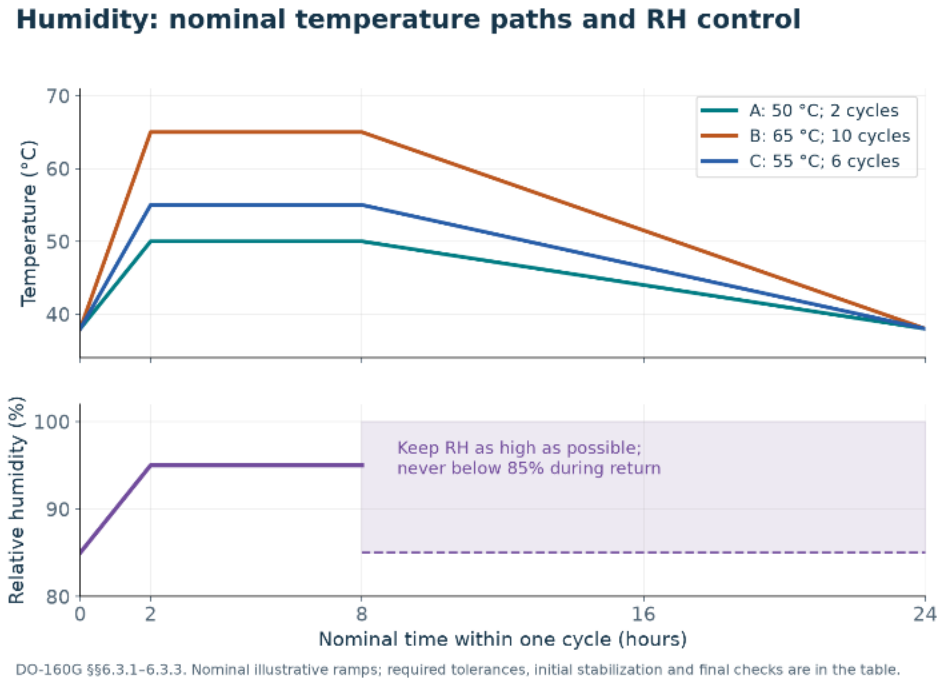
Contamination and material compatibility

Monitoring and evidence for functional acceptance



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# Humidity, water and fluids




## Humidity follows a prescribed cycle

Water exposure depends on faces and orientation

Chemical resistance depends on the actual fluid

FPD.DEV original teaching graphic; A-P02

# Temperature and humidity chambers




Cjp24; CC BY-SA 3.0

**Program the specified exposure cycle**

Measure the article as well as chamber air

Record recovery and functional checks

# Polarizer protection in wet environments

01 Humidity or salt fog can damage the polarizer

02 Optically bonded cover glass

03 Laminated PET film with a sealed polarizer edge

# Humidity reaches the optical stack

01 Moisture enters through edges, seals and materials

02 Absorption can change dimensions and adhesion

03 Condensation can affect insulation and touch

04 Separate haze, corrosion and electrical leakage

# A humidity test configuration

01 Install representative seals, vents and connectors

02 Follow the selected cycle and operating states

03 Log optical function, insulation and touch behaviour

04 Inspect before cleaning or opening the enclosure

# Water exposure and entry paths

01 Dripping, spraying and other categories differ

02 Orientation and cable routing affect entry

03 A front seal leaves other paths to assess

04 Record operation during the required exposure

# Fluid compatibility and service cleaning

01 Identify the fluids the installation can encounter

02 Test the actual coatings, seals and printed markings

03 Record concentration, contact and cleaning method

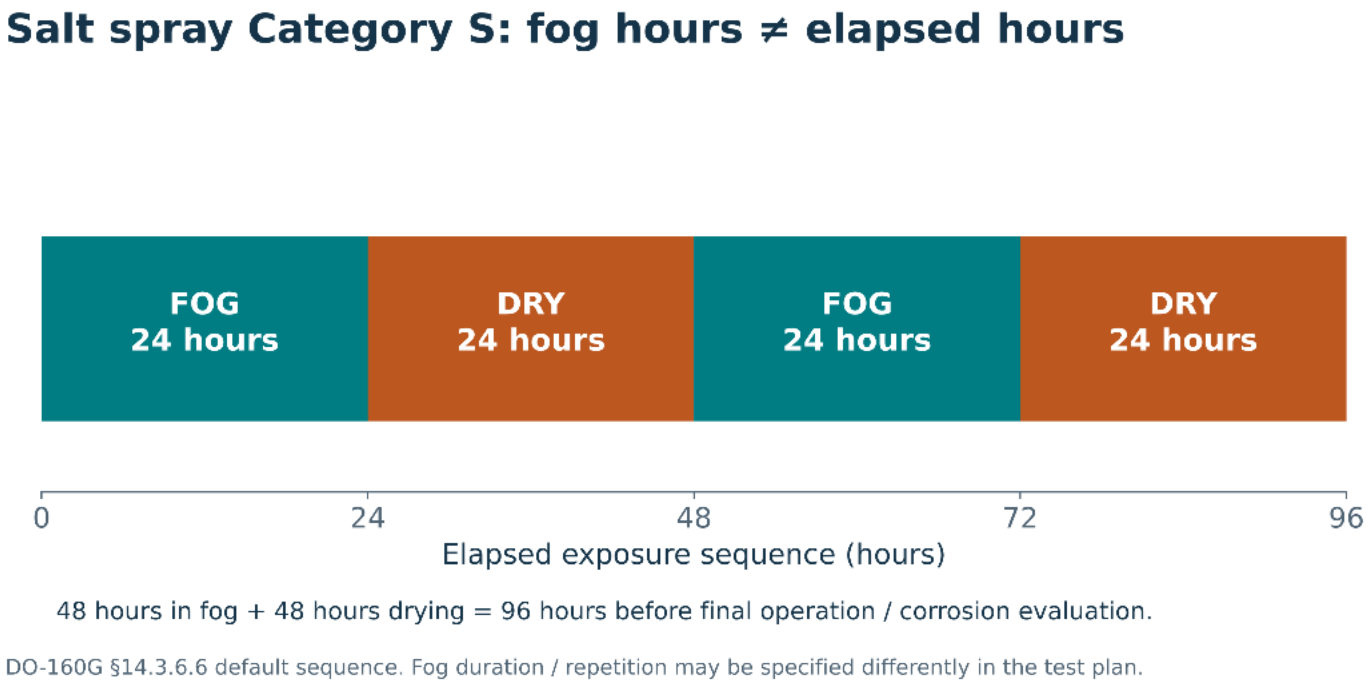
04 Inspect after exposure and required recovery

# Worked case: false touches when wet

| Observation | Evidence to retain | Decision basis |
| --- | --- | --- |
| False coordinate | Controller event log | Touch requirement |
| Unwanted command | Application output | System response |
| Normal image | Optical recording | Image requirement only |

## Illustrative investigation and evidence decision

# Salt spray, fungus, sand and dust




**Corrosion can degrade chassis electrical connections**

Materials evidence must match the formulation

Openings and cooling paths define exposure

FPD.DEV original teaching graphic; video layout A-P01

# Salt-spray test equipment




Cjp24; CC BY-SA 3.0

**Chamber, solution and collection controls**

Article orientation and exposure paths

Corrosion inspection and functional evidence

# Salt contamination and electrical paths

01 Salts can support conductive moisture films

02 Corrosion can impair shielding and connectors

03 Preserve the specified exposure and recovery

04 Check function and physical condition

# Dust, sand and exposed interfaces

01 Fine dust can enter gaps or obstruct cooling

02 Sand can abrade exposed optical surfaces

03 Motion can trap particles in seals and controls

04 Use the selected material and exposure method

# Fungus and material susceptibility

01 Assess organic materials and surface contamination

02 Use the adopted material and test provisions

03 Track substitutions in adhesives and coatings

04 Keep maintenance assumptions explicit



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## Next chapter

### Mechanical and Special Environments

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# DO-160 Display Qualification

## Mechanical and Special Environments

CHAPTER 4

## In this chapter

Shock and vibration levels from DO-160G

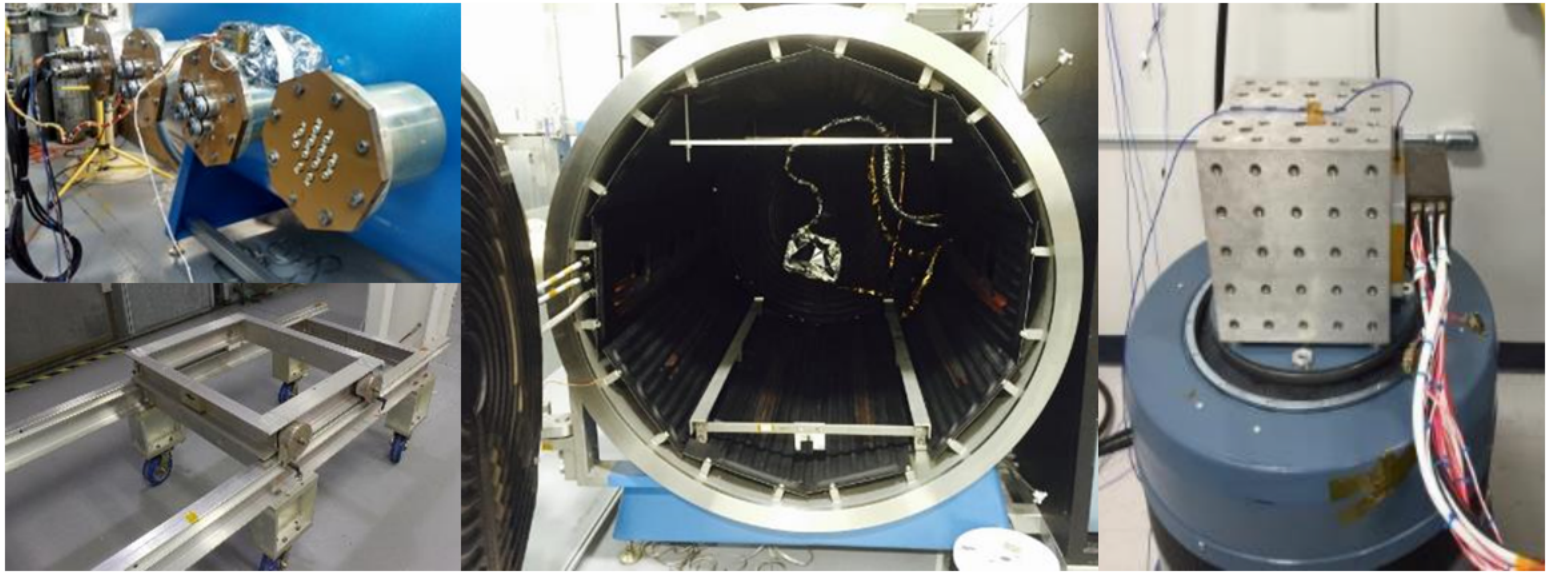
Resonance, damping and rotor harmonics

Display monitoring and special environments



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# Shock, vibration and the load path



**Fixture, fasteners and harness support matter**

Operational function and crash retention differ

Dynamic imagery reveals intermittent faults

NASA Goddard Space Flight Center / Engineering and Technology Directorate; NASA imagery; generally not subject to US copyright

# Fixed-wing and helicopter vibration



Terry Whalebone; CC BY 2.0

**Aircraft type, zone and method define coverage**

Rotor frequencies require an identified basis

A larger overall g value does not prove equivalence

# Vibration and shock quantities

| Exposure | Frequency or time | Severity quantity |
| --- | --- | --- |
| Sine vibration | Frequency in Hz | g peak or displacement |
| Random vibration | Frequency band in Hz | PSD $g^2$/Hz and g RMS |
| Mechanical shock | Pulse duration in ms | Peak g and pulse shape |

## Acceleration PSD describes mean-square acceleration per hertz

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

# Sine motion: frequency changes travel

| At 1 g peak | Peak displacement | Peak-to-peak travel |
|---|---|---|
| 10 Hz | 2.484 mm | 4.968 mm |
| 100 Hz | 0.02484 mm | 0.04968 mm |
| Relationship | a peak = $(2\pi f)^2$ x peak | Sine RMS = peak / √2 |

## Same 1 g peak input, very different displacement

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

# Random vibration: PSD and g RMS

| Illustrative input | Calculation | Result |
|---|---|---|
| PSD and bandwidth | 0.010 × (500 − 20) | 4.80 $g^2$ |
| Overall acceleration | √4.80 | 2.19 g RMS |
| PSD doubled | √(2 × 4.80) | 3.10 g RMS |

**g RMS = square root of the area under the acceleration PSD**

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

# DO-160G random curve B

| Frequency (Hz) | Acceleration PSD ($g^2$/Hz) |
|---|---|
| 10 | 0.012 |
| 40 | 0.012 |
| 100 | 0.002 |
| 500 | 0.002 |
| 2,000 | 0.00013 |

## Selected Figure 8-1 data: 10–2,000 Hz, listed 1.48 g RMS

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

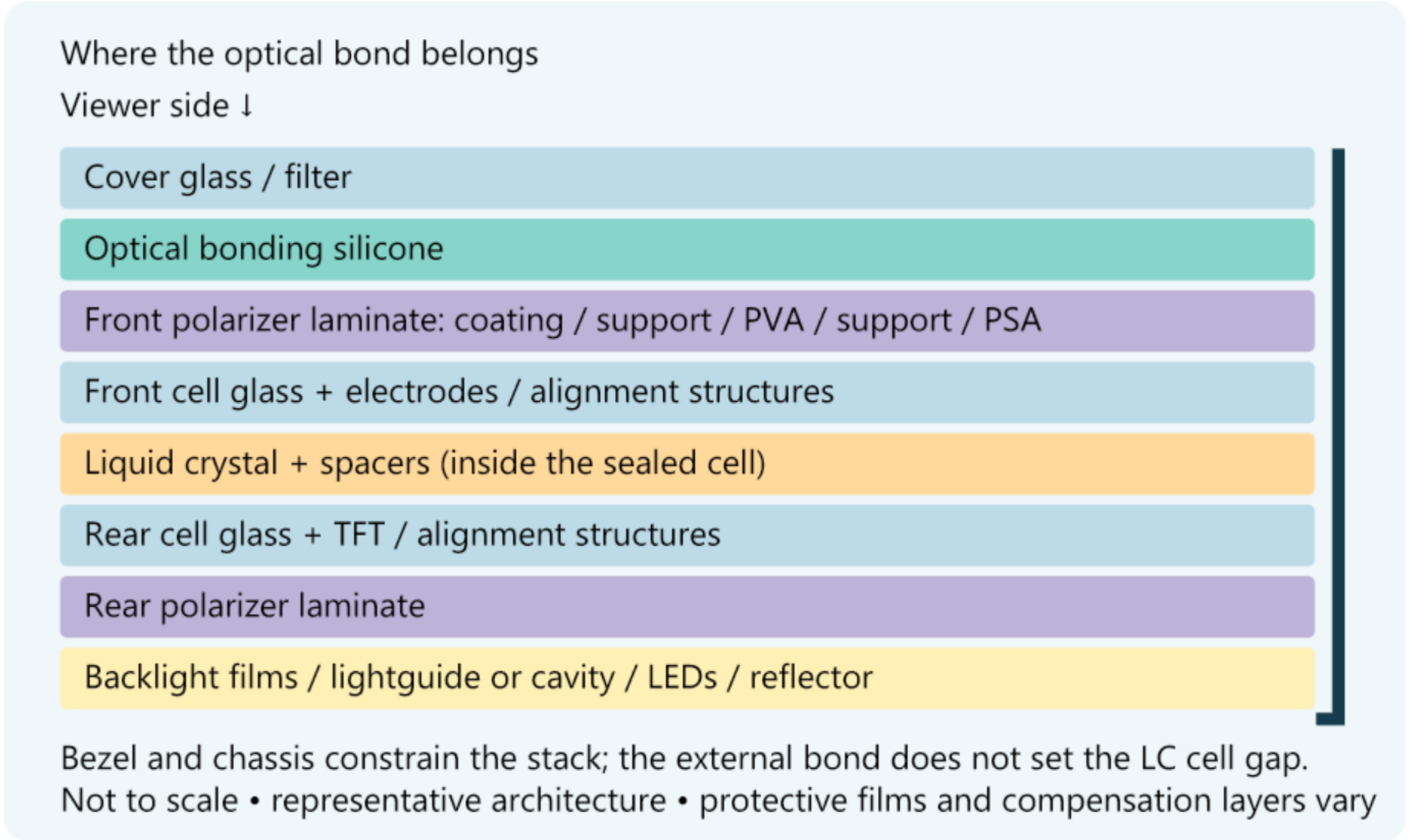
# Resonance scans and random exposure

| Step | Input and duration | Equipment state |
|---|---|---|
| Initial sine scan | 0.5 g peak, 10–2,000 Hz | Not operating |
| Random performance | Selected PSD, ≥1 h per axis | Operating |
| Final sine scan | Repeat initial scan | Compare resonances |
| All three axes | Scan rate ≤1 octave/min | Record response |

## Example scope: §8.5.2 standard random test, fixed-wing aircraft

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

# LCD cell gap and transient contrast




**FPD.DEV Optical Bonding course. Cell deformation can change contrast or cause flashes.**

# Mounting for viewability and survival

01 Support the module without twisting or point loading

02 Control gasket compression and cable forces

03 Allow thermal movement while retaining the assembly

# Isolation depends on the complete assembly

01 Isolation can reduce harmful transmitted motion

02 Resonance can amplify the display response

03 Verify motion, image quality and retention together

# Vibration fixture and installation

01 The fixture transmits the commanded input

02 Mount, fasteners and cable support affect response

03 Record control and response sensor positions

04 Justify any departure from the installed boundary

# Resonance and isolator trade-offs

01 Excitation near a natural frequency can amplify motion

02 Isolation depends on frequency and damping

03 Soft mounts increase displacement and clearance needs

04 Temperature and ageing can change mount behaviour

# Natural frequencies of a display

**01** Simple model: $f_n = (1 / 2\pi) \sqrt{(k / m)}$

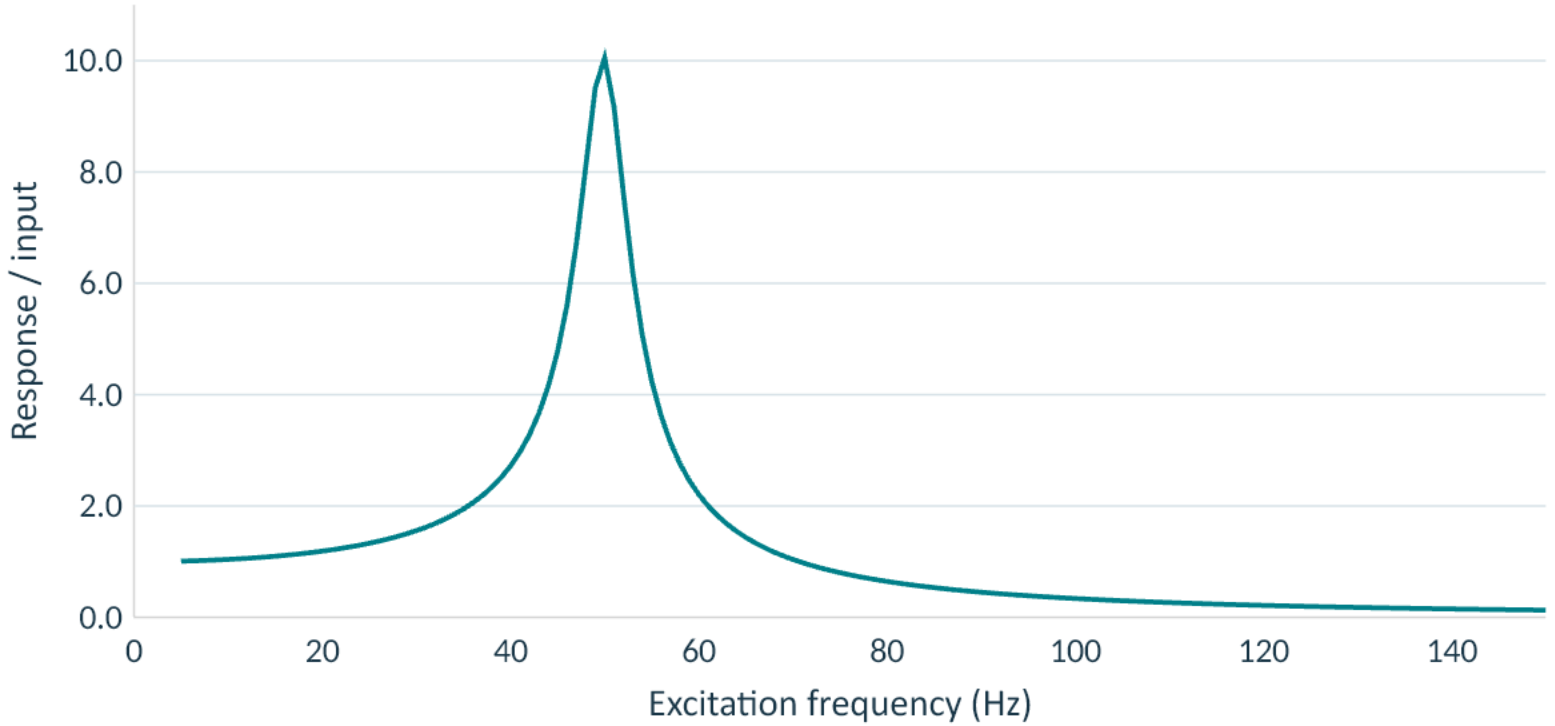
**02** Higher stiffness raises the natural frequency

**03** More supported mass lowers it

**04** Real assemblies have several modes and shapes

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

# Resonance: input and response




**Illustrative fn = 50 Hz**

5% damping: about 10× at fn

Play to compare input and response

Animated explanation in the course player. Analytical model with stated assumptions.

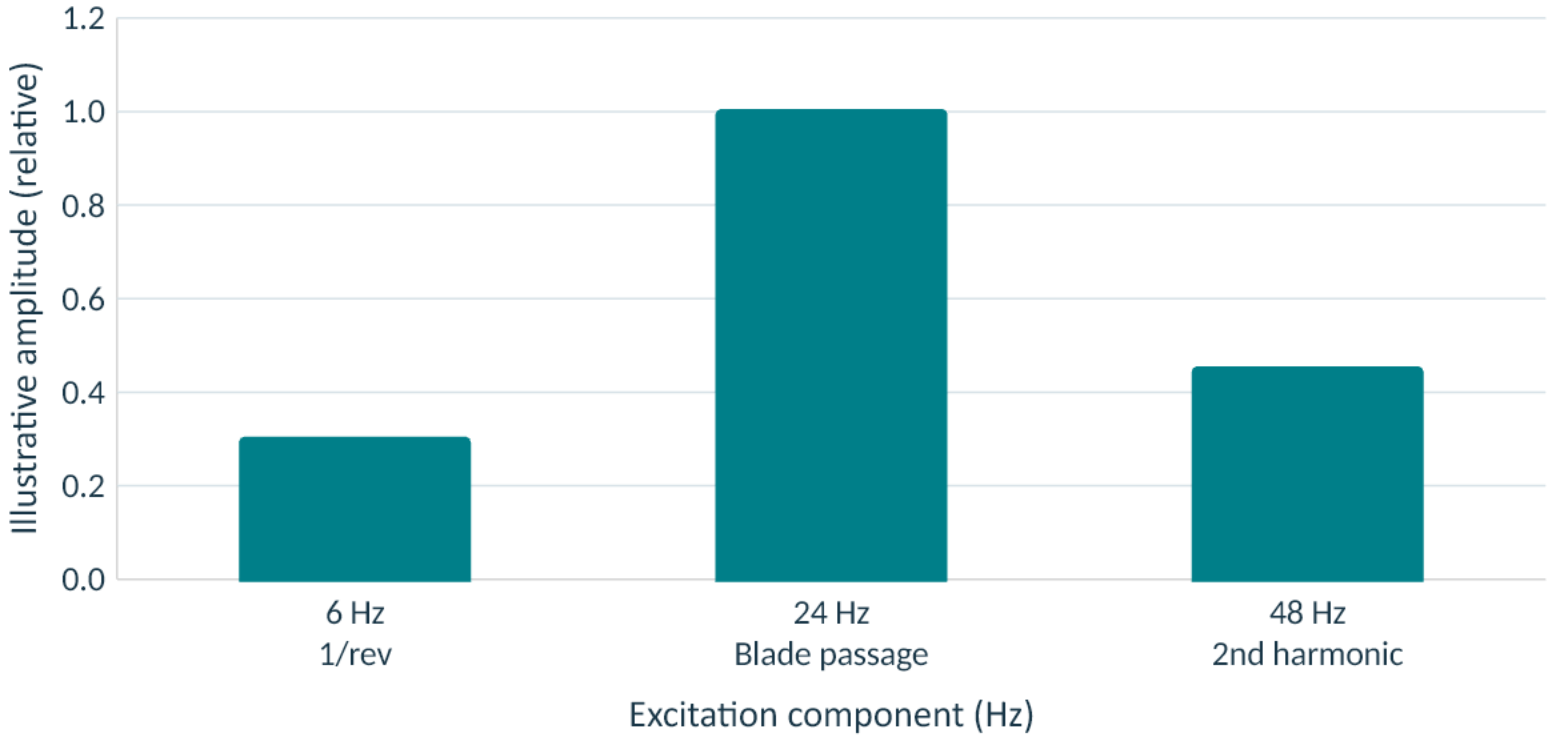
# Damping limits resonance

| Damping ratio | Response / input at fn | Response to 0.5 g peak |
|---|---|---|
| 5% | 10.05 | 5.02 g peak |
| 10% | 5.10 | 2.55 g peak |
| 20% | 2.69 | 1.35 g peak |

## Linear base-excitation model, at fn = 50 Hz

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

# Harmonics and structural modes




**360 rpm = 6 revolutions/s**

Four blades: 24 Hz blade passage

Second blade-passage harmonic: 48 Hz

Animated explanation in the course player. Analytical model with stated assumptions.

# Helicopter instrument-panel tones

| Zone 2 / G tone | DO-160G relationship | 360 rpm, 4 blades |
|---|---|---|
| f1 | NM × FM | 24 Hz |
| f2 | 2 × NM × FM | 48 Hz |
| f3 and f4 | No entries for Zone 2 | Other zones differ |

## Table 8-2a excerpt: Zone 2, curve G

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

# Helicopter curve G acceleration

| Tone | Performance (g peak) | Endurance (g peak) |
|---|---|---|
| 24 Hz | 0.04 × 24 = 0.96 | 2.5 |
| 48 Hz | 1.6 | 2.5 |
| External-airflow case | Multiply sine levels by 1.5 | When note 2 applies |

## Selected Table 8-2b values applied to the 24 Hz / 48 Hz example

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

# Sine-on-random: two severity measures

| Random background | Performance | Endurance |
|---|---|---|
| W0 ($g^2$/Hz) | 0.010 | 0.020 |
| Listed random g RMS | 2.75 | 3.89 |
| Add sine components | Use each peak² / 2 | Then sum mean squares |

## Table 8-2b and Figure 8-6: background and discrete tones

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

# Image stability during vibration

01 Use moving and stationary reference patterns

02 Capture brief flashes, dropouts and connector events

03 Separate optical effects from camera artefacts

04 Correlate the image with mechanical measurements

# Shock survival and retained function

01 Operating shock and crash safety have different aims

02 Record axes, mounting and specimen state

03 Inspect load paths and retained attachments

04 Apply the acceptance criteria for the selected test

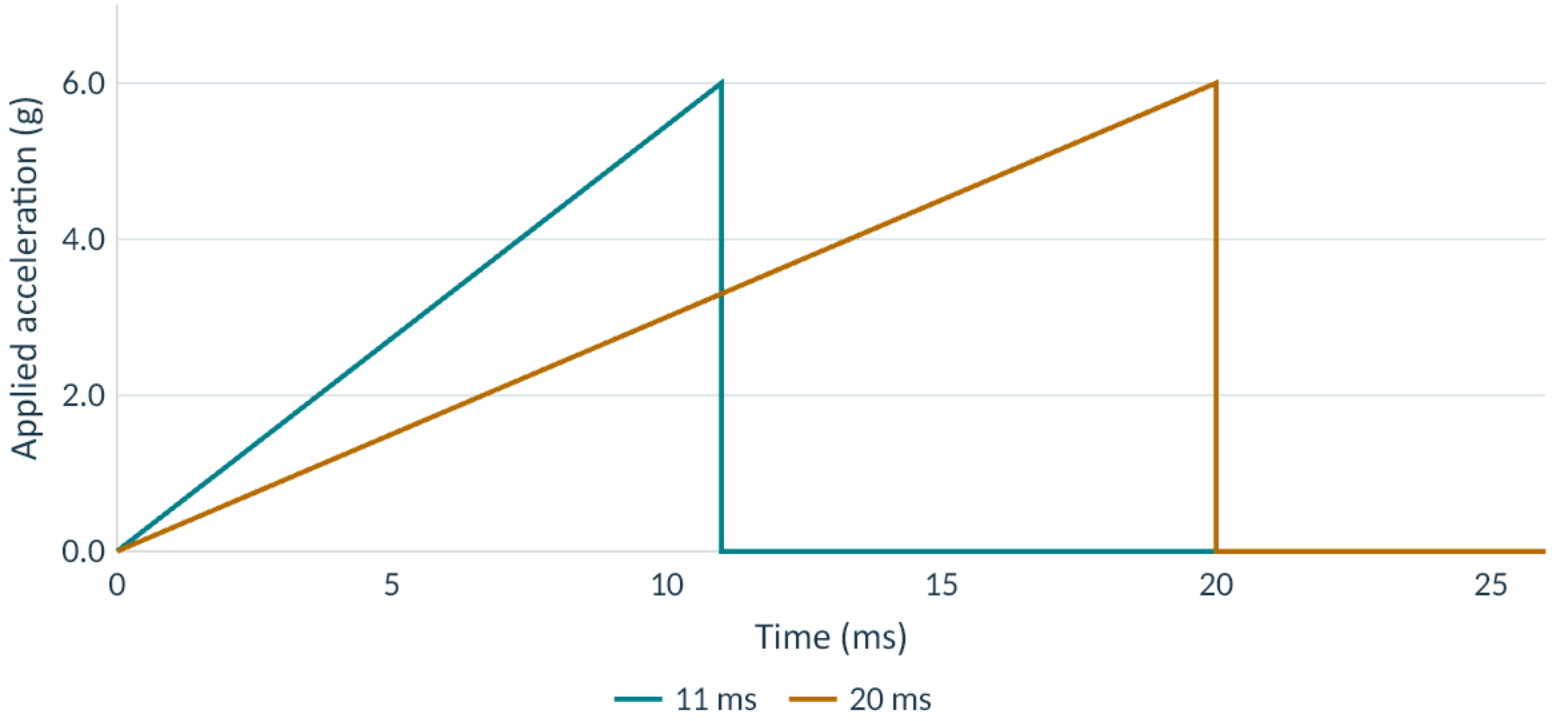
# DO-160G shock pulse examples

| Test example | Peak and nominal duration | Count / scope |
|---|---|---|
| Operational, standard | 6 g, 11 ms | 3 per orientation |
| Operational, low frequency | 6 g, 20 ms | 3 per orientation |
| Crash impulse | 20 g, applicable 11 / 20 ms | 1 per orientation |
| Crash sustained | Table 7-1 loads | ≥3 s per load direction |

## Terminal sawtooth pulses; category and procedure determine applicability

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

# Shock duration and ringing




**A shock has a broad frequency spectrum**

11 ms and 20 ms are durations

Play to compare ideal 6 g pulses

Animated explanation in the course player. Analytical model with stated assumptions.

# Crash sustained loads: one table row

| Aircraft load direction | Minimum sustained acceleration |
|---|---|
| Up | 3 g |
| Down | 6 g |
| Forward | 9 g |
| Aft | 1.5 g |
| Left and right | 4 g each |

## Table 7-1 excerpt: fixed-wing transport, known fixed orientation (F)

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

# Monitoring the display response

01 Measure fixture input and selected structural responses

02 Synchronize acceleration, image and interface logs

03 Check glass, bond edges, boards and connectors

04 Compare modes before and after the exposure

Source and scope in narration and reading. Selected DO-160G data / FPD.DEV teaching examples.

# Special environments and material scope

01 Explosion proofness: ignition in a flammable atmosphere

02 Icing: allocated freezing-moisture exposure

03 Fire: applicable category and installation requirements

# Make the applicability decision reviewable

01 Identify the installation exposure and requirement

02 Match material, thickness and assembly to evidence

03 Record the rationale, owner and unresolved inputs

# Special environments: a scope record

| Subject | Installation question | Record |
| --- | --- | --- |
| Magnetic effect | Compass proximity? | Separation basis |
| Icing / explosion | Relevant exposure? | Applicability rationale |
| Fire / flammability | Which requirement? | Material / equipment scope |

**A reasoned applicability decision for each section**

# Enhancements create coupled trade-offs

01 Brighter backlights add power and heat

02 EMI layers can reduce optical transmission

03 Heaters affect power, optics and touch

04 Recheck the complete enhanced assembly



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## Next chapter

### Power and Electrical Transients

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# DO-160 Display Qualification

## Power and Electrical Transients

CHAPTER 5

## In this chapter

Input power, interruptions and recovery

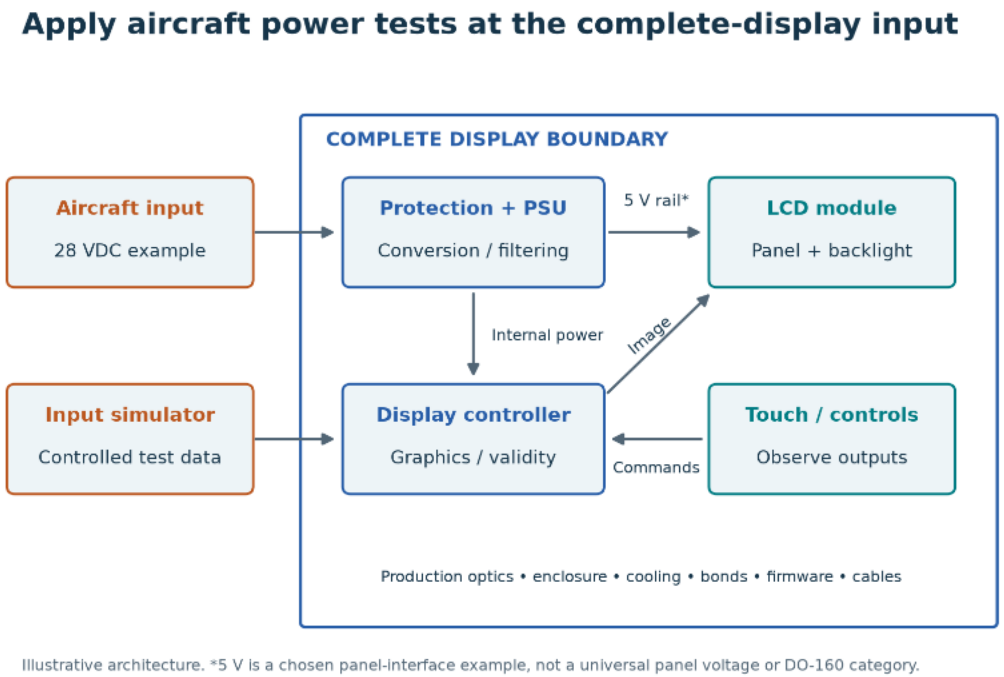
Spikes, ripple and protection behaviour

Worked power and data-validity cases



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# Aircraft power reaches the entire display




**Aircraft connector, protection and conversion**

Internal rails, processing, backlight and heater

Image integrity, controls and recovery

FPD.DEV original teaching graphic; A-P02

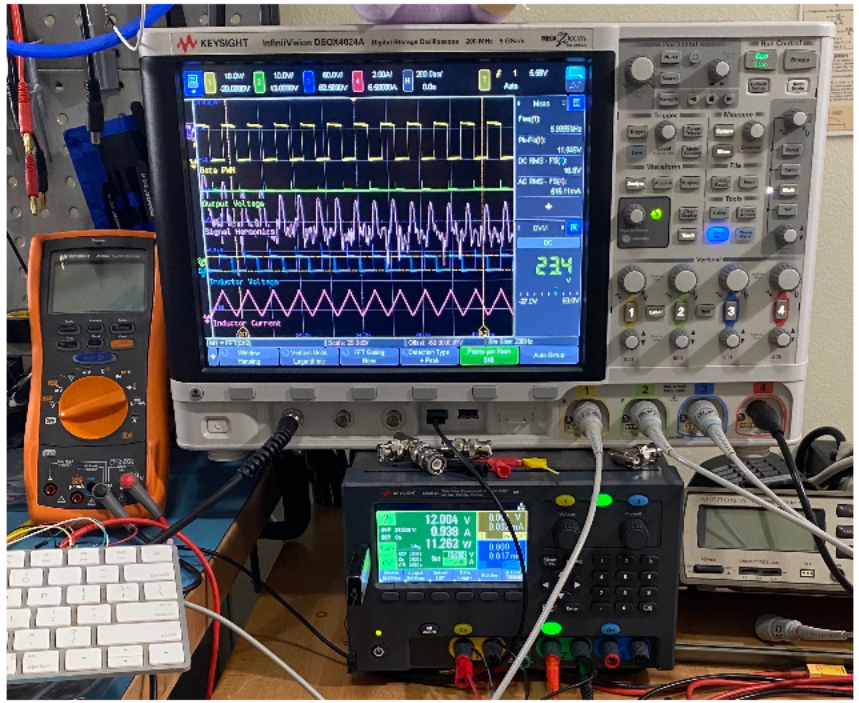
# Aircraft and vehicle power requirements

01 MIL-STD-704: aircraft input-power characteristics

02 DO-160: allocated power and electrical tests

03 MIL-STD-1275: military ground-vehicle 28 VDC

# Power stimulus and electrical monitoring




## Supply and disturbance source

Oscilloscope and multimeter measurements

Synchronized image, reset and recovery record

Radarvector; source crop by Pittigrilli; CC BY-SA 4.0

# Power qualification at the display input

01 Identify AC or DC supply and the applicable category

02 Include conversion, heater and backlight loads

03 Measure the waveform at the equipment terminals

04 Document source impedance and the test harness

# Interruptions, brownouts and restart

01 Track internal rails and the visible image

02 Define permitted interruption and recovery

03 Detect frozen data after restart

04 Verify command outputs and saved configuration

# Hold-up energy: an initial estimate

| Assumption | Value | Calculation |
| --- | --- | --- |
| Load and duration | 20 W, 0.020 s | Energy = 0.40 J |
| Voltage window | 28 V to 18 V | $28^2 - 18^2 = 460\ V^2$ |
| Ideal capacitance | 0.80 / 460 F | About 1,740 µF |

**Illustrative ideal calculation, before design margins**

# Voltage spikes and input protection

01 Identify the specified pulse at the test boundary

02 Assess clamp current and residual voltage

03 Account for wiring inductance and protection layout

04 Check function after repeated prescribed stimuli

# Audio-frequency ripple on power

01 Section 18 injects interference on the power input

02 Ripple can modulate backlight or reference circuits

03 Sweep the applicable range with required loading

04 Observe image, touch and interface behaviour

# Heater and backlight load transitions

01 Cold start can combine several peak loads

02 Dimming changes the electrical operating mode

03 Control transitions can disturb sensitive rails

04 A mode matrix makes the selected cases traceable

# Worked case: recovery with stale data

| Event | Evidence | Acceptance question |
| --- | --- | --- |
| Power returns | Input and rail trace | Electrical recovery? |
| Image returns | Timed video | Required recovery time? |
| Map stays frozen | Data and display log | Valid current information? |

## Illustrative power interruption result



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## Next chapter

### EMC, Lightning and ESD

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# DO-160 Display Qualification

EMC, Lightning and ESD

CHAPTER 6

## In this chapter

EMC paths, configuration and monitoring

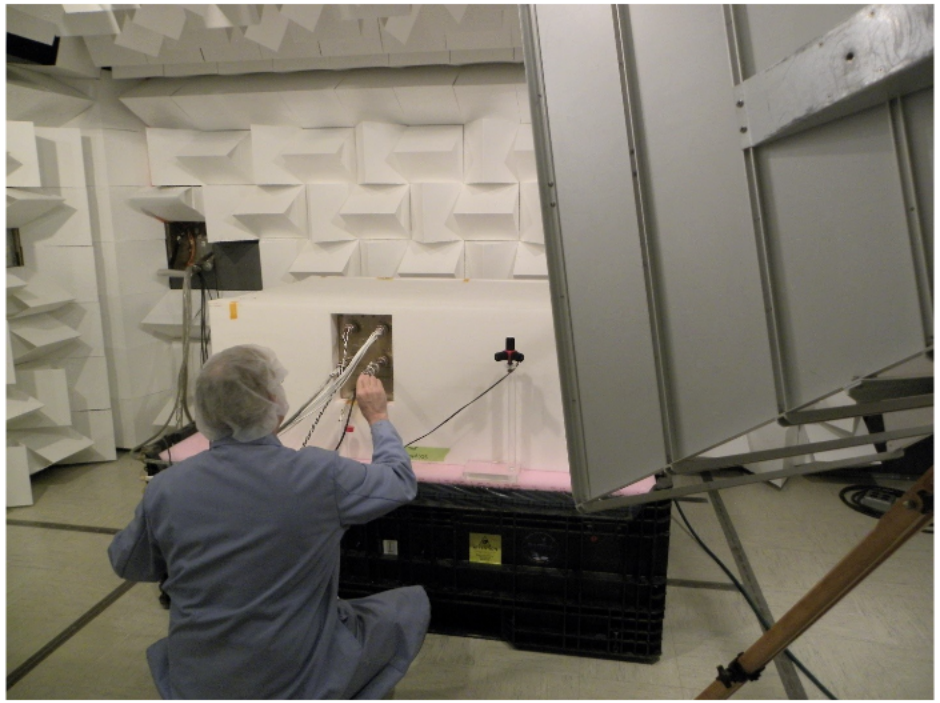
Lightning methods and installation assumptions

ESD behaviour and corrective changes



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# Emissions and susceptibility



NASA Glenn Research Center; NASA imagery; generally not subject to US copyright

**Section 20: response to RF disturbance**

Section 21: RF energy from the display

Harness, enclosure and modes belong in the report

# Equipment EMC and aircraft HIRF

01 Equipment tests establish defined capability

02 Aircraft coupling and shielding establish exposure

03 Installed compatibility closes a separate question

# Equipment EMI and system E3

01 MIL-STD-461: equipment and subsystem EMI

02 MIL-STD-464: system electromagnetic effects

03 DO-160 results need a requirement-level comparison

# Coupling paths through the installation

01 Cables can conduct or receive interference

02 Seams and apertures affect enclosure shielding

03 Bonding and shield termination define current paths

04 The test configuration must represent those paths

# Induced signals and RF susceptibility

01 Section 19 addresses induced signals in interconnects

02 Section 20 addresses conducted and radiated RF

03 Use each method and its calibrated stimulus

04 Record performance during the applied disturbance

# Emissions depend on mode and harness

01 Section 21 measures emissions from the equipment

02 Clocking, dimming and heaters can change the spectrum

03 Use representative cables and terminations

04 Compare corrected measurements with applicable limits

# A trustworthy EMC monitoring channel

01 The monitoring system can disturb the test

02 Fibre links can reduce unintended conductive paths

03 Verify event timing and detection sensitivity

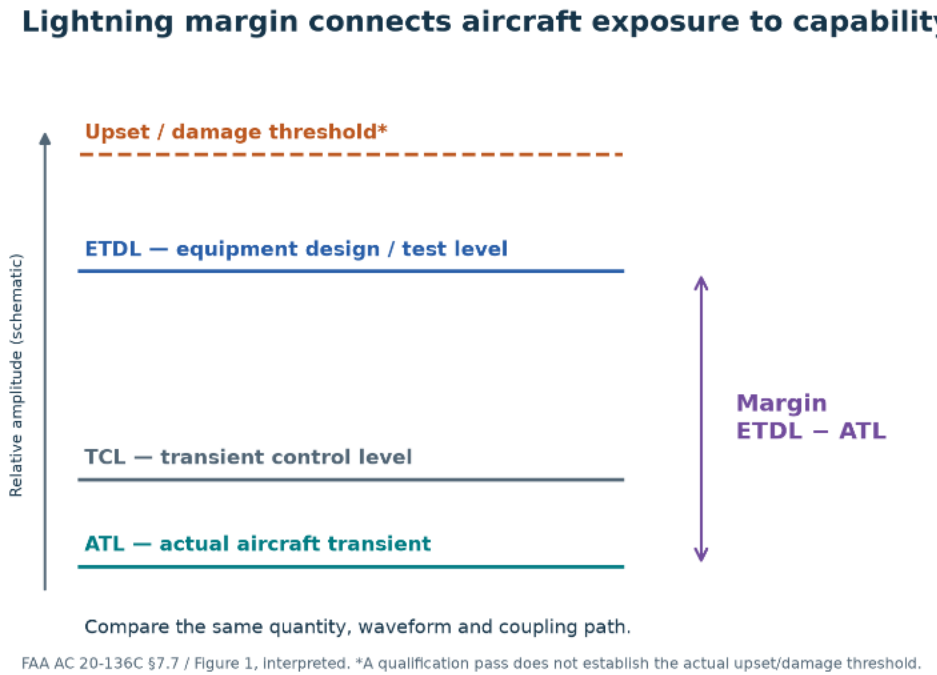
04 Distinguish product failure from monitor failure

# Worked case: touch commands during RF

| Record | Purpose | Related check |
| --- | --- | --- |
| RF condition | Reproduce the exposure | Selected method |
| Touch and command logs | Locate the faulty function | False input criterion |
| Revised configuration | Identify the correction | Touch and EMC regression |

## Illustrative susceptibility investigation

# Lightning capability and installed exposure




**Section 22: induced transients**

Section 23: direct effects

Compare matching waveforms, paths and quantities

FPD.DEV original teaching graphic; A-P02

# Lightning level selection has a scope

01 FAA Table 4 concerns LCL A displays

02 Equipment and connected wiring both matter

03 A protected box can have exposed cable paths

# ESD includes control-output behavior




**Accessible surfaces and discharge paths**

Production optical stack, bezel and bonding

False commands, resets and persistent faults

Eeroalk; CC BY-SA 3.0

# Lightning evidence follows the interface

01 Define installation-induced exposure at the equipment

02 Match waveform, level and test method

03 Include cable shields, returns and protection paths

04 Keep equipment evidence tied to aircraft assumptions

# Pin injection and cable methods

01 Pin injection assesses damage tolerance

02 Cable methods assess functional upset tolerance

03 Use the selected waveform and calibration procedure

04 Cable tests can also reveal damage

# Direct effects and induced transients

01 Section 23 addresses direct lightning effects

02 Section 22 addresses induced transients

03 Installation exposure determines applicability

04 Survival of one exposure gives limited evidence

# ESD at the operator interface

01 Air discharge at accessible human-contact points

02 Section 25 excludes connector pins

03 Monitor touch, controls, data and visible image

04 Check recovery and latent functional changes

# Protection changes and residual risk

01 A protection device can alter capacitance and leakage

02 Shield changes can affect touch and transmission

03 Bonding changes affect transient current paths

04 Repeat the evaluations affected by the correction



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## Next chapter

### Integration and Qualification Practice

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# DO-160 Display Qualification

## Integration and Qualification Practice

CHAPTER 7

## In this chapter

Installed performance and product claims

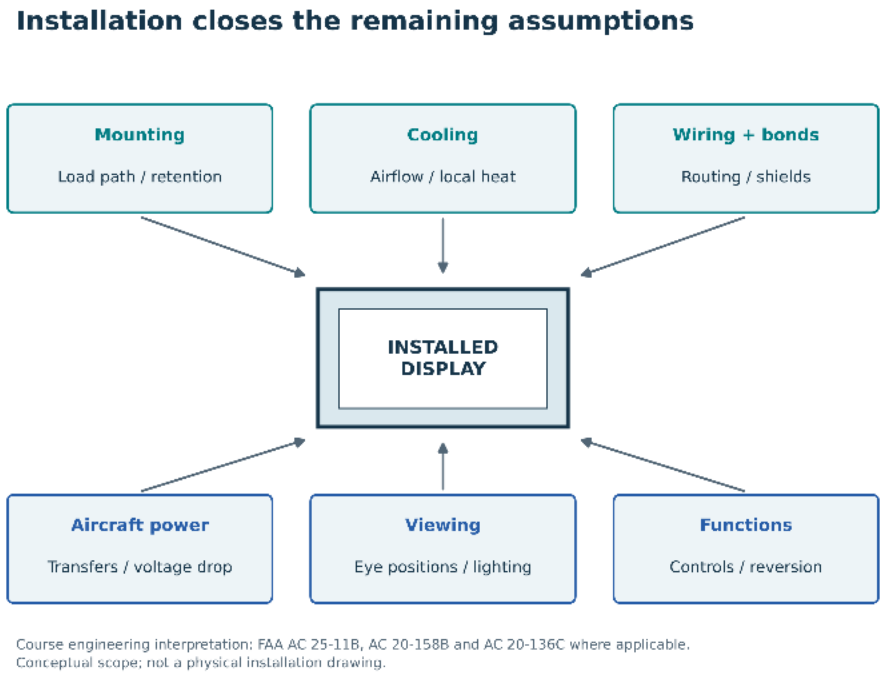
Test plans, uncertainty and anomaly records

Capstone trade study and evidence review



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# The installed display




**Mounting and cooling match the assumptions**

Power, bonds and harness preserve the boundary

Viewing and controls work in the crew environment

FPD.DEV original teaching graphic; video layout A-P01

# Display performance and crew use

01 AS8034: airborne display performance

02 MIL-STD-3009: NVIS display emission

03 MIL-STD-1472: military human engineering

# Development assurance and installation

01 DO-178C: software assurance

02 DO-254: electronic hardware assurance

03 ARP4754 / ARP4761: development and safety

# Qualification, production and service life

01 Environmental qualification supports the design

02 Production acceptance checks delivered units

03 Life and reliability claims need their own basis

# Readability and spectral performance

01 Use the intended viewing directions and ambient light

02 Check dimming, colour and information discrimination

03 Evaluate spectral requirements in each relevant mode

04 Treat the final optical stack as the measured product

# Operating envelope and product claims

01 State ambient, internal and functional limits

02 Identify permitted warm-up or degraded modes

03 Name the tested assembly and operating conditions

04 Keep enhanced capability tied to its evidence

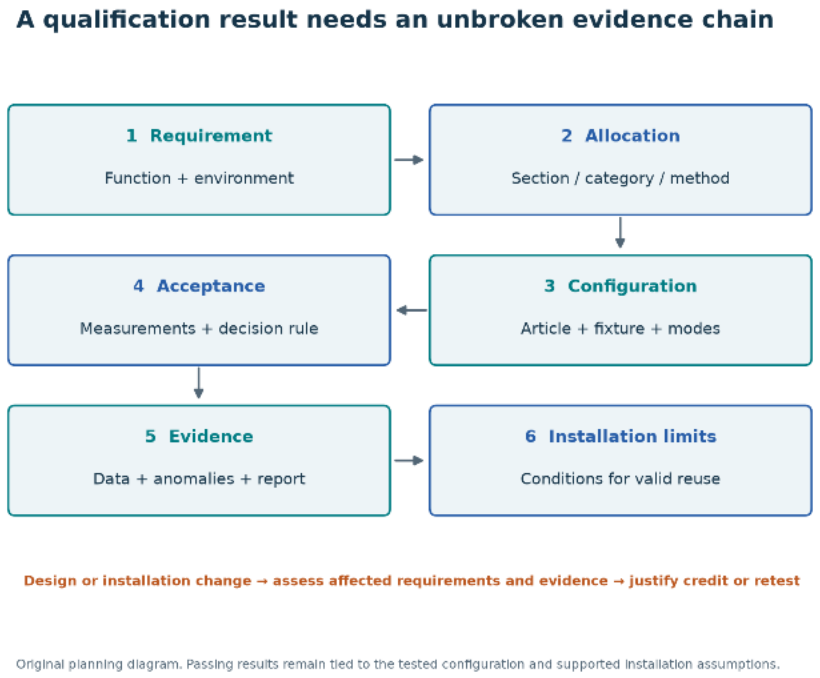
# The test contract buys evidence

01 Agreed matrix and acceptance criteria

02 Representative articles, fixtures and modes

03 Data, anomalies, retests and installation limits

# Closing a qualification matrix row




**Requirement and installation source**

Exact configuration and as-run evidence

Disposition and remaining installation limits

FPD.DEV original teaching graphic; A-P02

# A test-ready requirement record

| Record field | Example content | Purpose |
| --- | --- | --- |
| Requirement | Hot ambient contrast | Function to demonstrate |
| Method and state | Temperature + light geometry | Reproducible conditions |
| Result and evidence | Ratio, uncertainty, trace | Reviewable decision |

## Illustrative row structure for the qualification matrix

# Measurement uncertainty at acceptance

01 Choose a decision rule before testing

02 Keep calibration and instrument range traceable

03 Account for geometry and repeatability

04 Report a borderline result with its uncertainty

# Test sequence and specimen history

01 Record previous exposure and any repairs

02 Select sequence from requirements and the test plan

03 Control changes between tests

04 Preserve evidence for cumulative effects

# Changes and anomalies

01 A changed part can alter several failure paths

02 Original failures remain in the record

03 Credit and retest follow the impact assessment

# Worked example: changing the cover glass

01 Record glass, adhesive, mass and geometry changes

02 Review optical, thermal and mechanical effects

03 Justify retained credit and targeted verification

# An anomaly record preserves the event

01 Capture time, stimulus, mode and configuration

02 Separate observed behaviour from suspected cause

03 Retain the failed run and investigation evidence

04 Approve correction and retest scope explicitly

# A change-impact review across disciplines

| Changed property | Potential effect | Evidence review |
| --- | --- | --- |
| Resistance / control | Power and warm-up | Thermal and power tests |
| Conductive layer | Touch and EMC | Functional / EMC checks |
| Bonding / optics | Stress and transmission | Mechanical / optical checks |

## Illustrative substitution: new transparent heater

# Capstone: the bonded touch display

01 10-inch display; nominal 28 VDC input

02 Pressurized flight deck; four structural mounts

03 Several environmental allocations remain open

# Capstone deliverables

01 Boundary and open-input list

02 All-section matrix and two procedure outlines

03 Monitoring, supplier evidence and installation checklist

# Capstone review points

01 A temperature request does not select a category

02 22 minutes describes only the ideal ramp

03 65,000 ft requires an aircraft or customer basis

# Second application: a helicopter

01 Unpressurized location and different harness

02 Isolators change mechanical and bonding assumptions

03 Common evidence needs a documented comparison

# Capstone: a military derivative

01 Allocate aircraft, mission and handling requirements

02 Map shared evidence and uncovered conditions

03 Reassess a military ground-vehicle installation

# Capstone: a constrained design choice

01 Bright cockpit display with cold-start requirement

02 Bonded heater, touch layer and EMI shield

03 Limited power budget and fixed mounting envelope

04 Propose evidence before selecting the final stack

# Capstone review: what earns acceptance

01 Every claim has a measurable criterion

02 Every selected method has a configuration

03 Interactions and failure recovery have evidence

04 Open items have owners and closure conditions

# Knowledge check

**01** A panel report covers the complete display?

**02** A survival result proves operation?

**03** An emissions pass closes HIRF compliance?

# Knowledge check: the evidence gaps

01 Panel evidence has limited configuration coverage

02 Survival and operating criteria apply to different states

03 Emissions, susceptibility and aircraft HIRF differ

# Standards knowledge check

01 Storage pass versus powered operation?

02 Equipment EMI versus system E3?

03 Does a common chamber establish equivalence?

# Standards review: evidence and scope

01 Operating evidence must cover powered behavior

02 MIL-STD-461 equipment / MIL-STD-464 system

03 Procedure and acceptance determine coverage



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## Next: glossary

### DO-160 glossary

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# DO-160 Display Qualification

Course glossary

COURSE GLOSSARY

## In this chapter

Qualification and evidence terms

Environmental and interface terms

Materials and mounting terms



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# Glossary: qualification evidence

**01** EUT: equipment under test

**02** EQF: Environmental Qualification Form

**03** Configuration: identified hardware, software and arrangement

# Glossary: environments and interfaces

**01** EMC: electromagnetic compatibility

**02** HIRF: high-intensity radiated fields

**03** ESD: electrostatic discharge

**04** NVIS: night vision imaging system

# Glossary: timing, pressure and margin

**01** Stabilization: the defined equipment condition

**02** Absolute pressure: referenced to vacuum

**03** ATL / ETDL: actual transient / equipment transient design level

# Materials and mounting terms

01 CTE: coefficient of thermal expansion

02 Adhesive / cohesive: interface / internal failure

03 Cell gap: thickness of the liquid-crystal layer

04 Transmissibility: response relative to input



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## Course complete

**Review your qualification plan and evidence**

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