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Hoist and Human External Cargo

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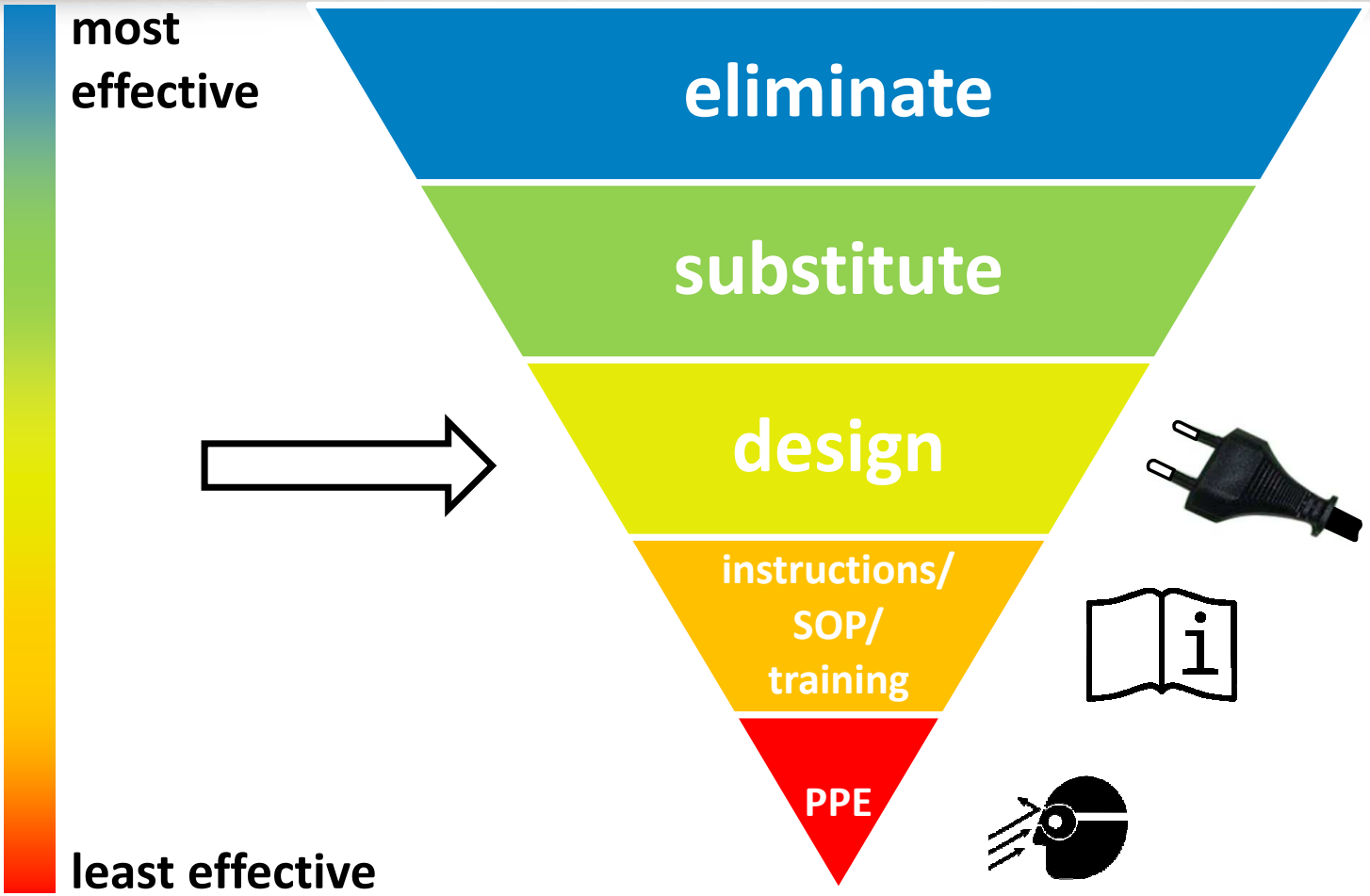
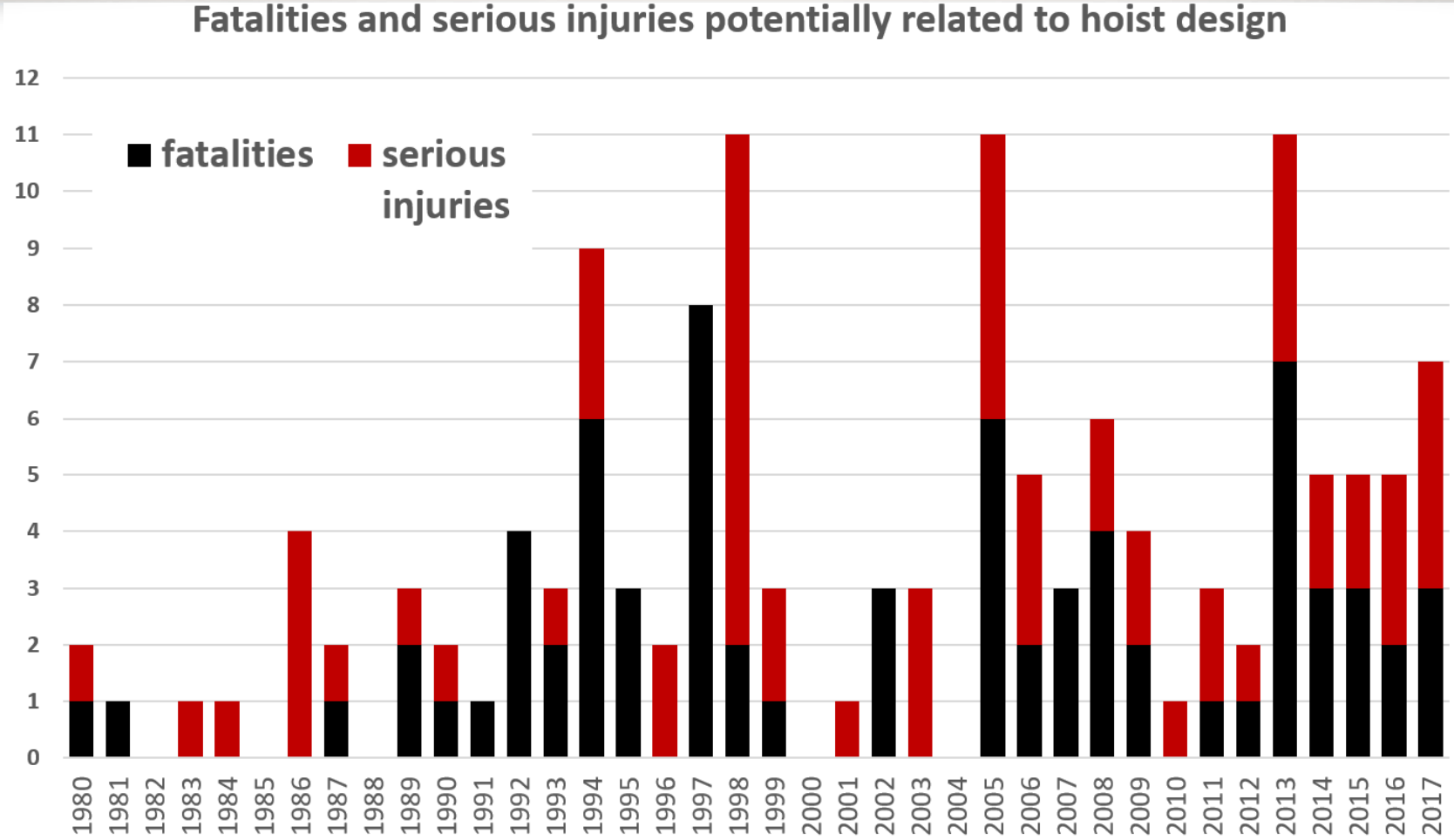
Hierarchy of hazard controls



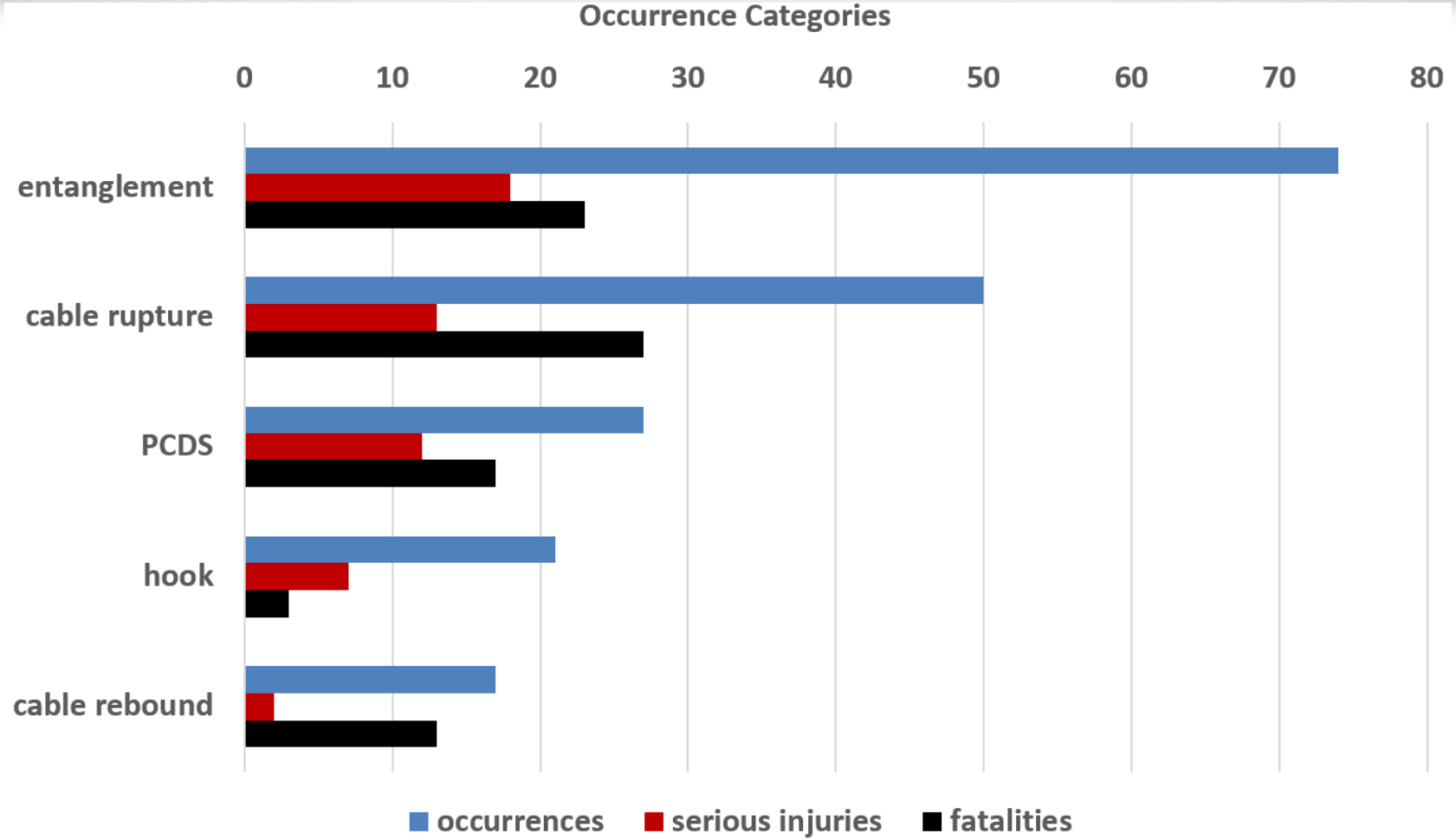
Service history

- database of occurrences related to hoist design ONLY
- 300+ events dating back to
- 22 Feb. 1955, in Maitland, New South Wales, Australia, a Royal Australian Navy Sycamore crashed following a cable rebound, 2 fatalities

Service history for hoist

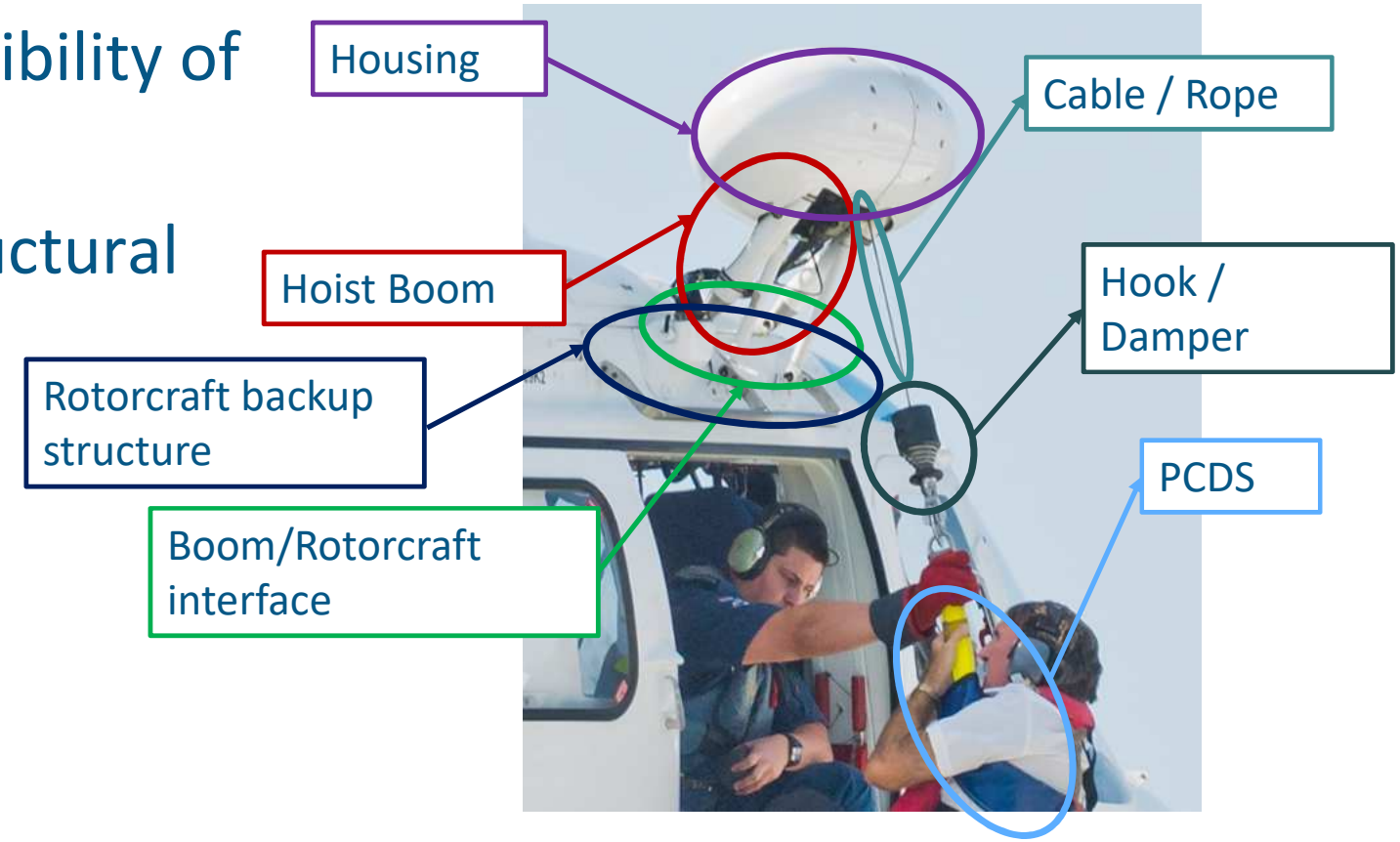


Service history for hoist



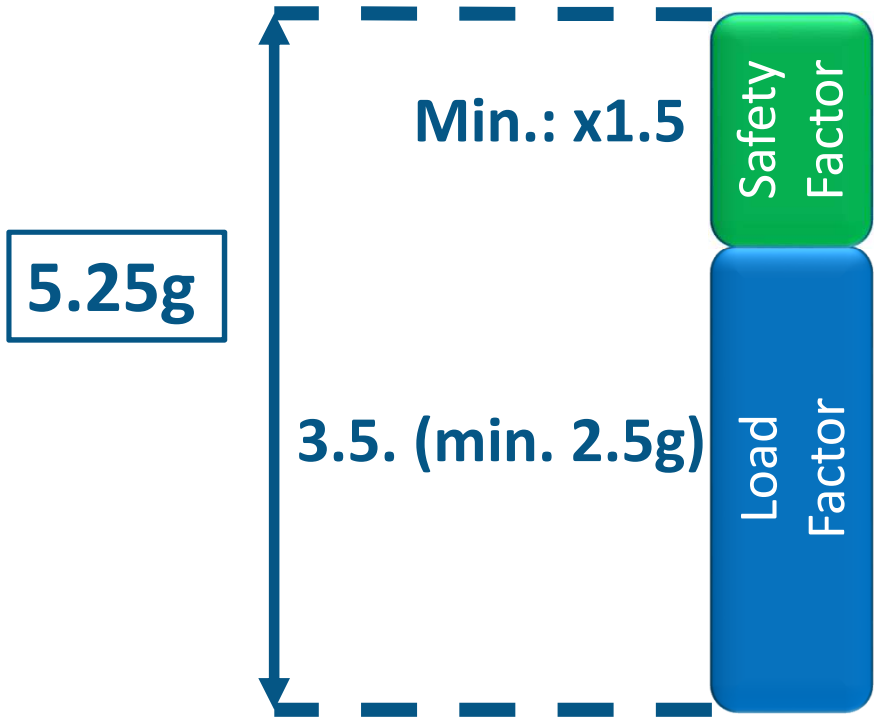
System and Structures

- Majority of hoist is under primary responsibility of Systems Expert
- Examples of structural parts are:



Hoist and HEC static strength

- **FAR/CS 27/29.865 (since 1999)**



Limit to Ultimate

(If no test: x3.0)

Human External Cargo (HEC)

Min. Person weight: 101,2kg

Load application: min. 30° cone (all directions)

CS 29.865 External loads

- limit static load equal to 3.5 for Human External Cargo (HEC)
- or some lower load factor, not less than 2.5, approved under CS 29.337 through 29.341
  multiplied by the maximum external load for which authorisation is requested.
- Minimum angle 30° in all directions (cone)
- Minimum person weight: 101.2 kg (223 pound)

Load factor between 2.5 and 3.5g

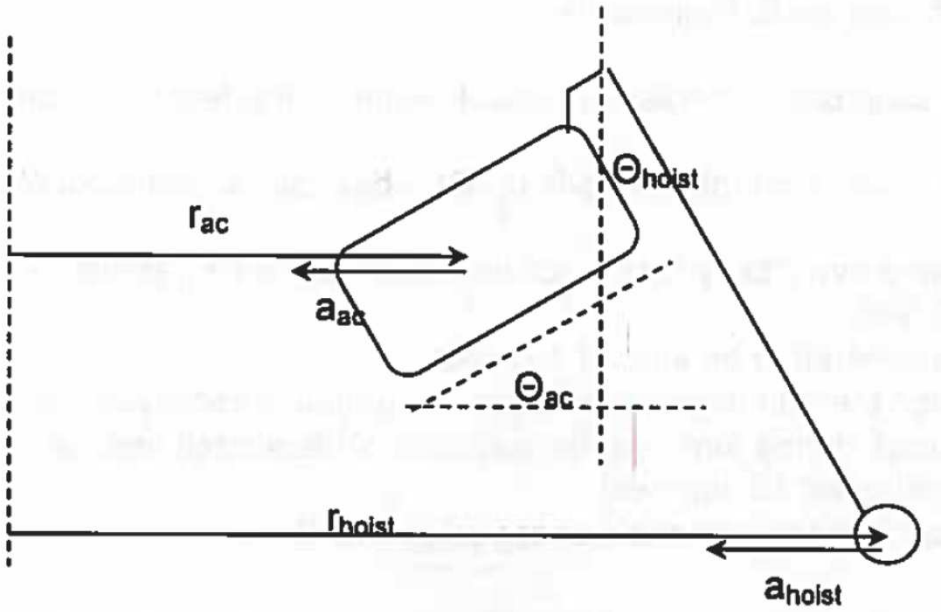
- Information to substantiate load factor between 2.5 and 3.5 usually only known by the TC holder
- Possible through “realistic” operational limitations
  - Speed
  - Weight
  - Angle between cable and rotorcraft
  - **NOT** g-meter at rotorcraft level

All operational limitations have to be indicated to the flight crew

Hoist dynamic load factors

- AMC 29.865
  […] dynamic load factors (load factor at cargo is higher than at the aircraft) should be applied where appropriate
- Examples:
  - Turns / Climbs
  - quick stops
  - aerodynamics
  - load pickups (stationary/moving surface)
  - Rapid reeling direction reversal
  - cable dynamics (elasticity, whip traveling wave,…)

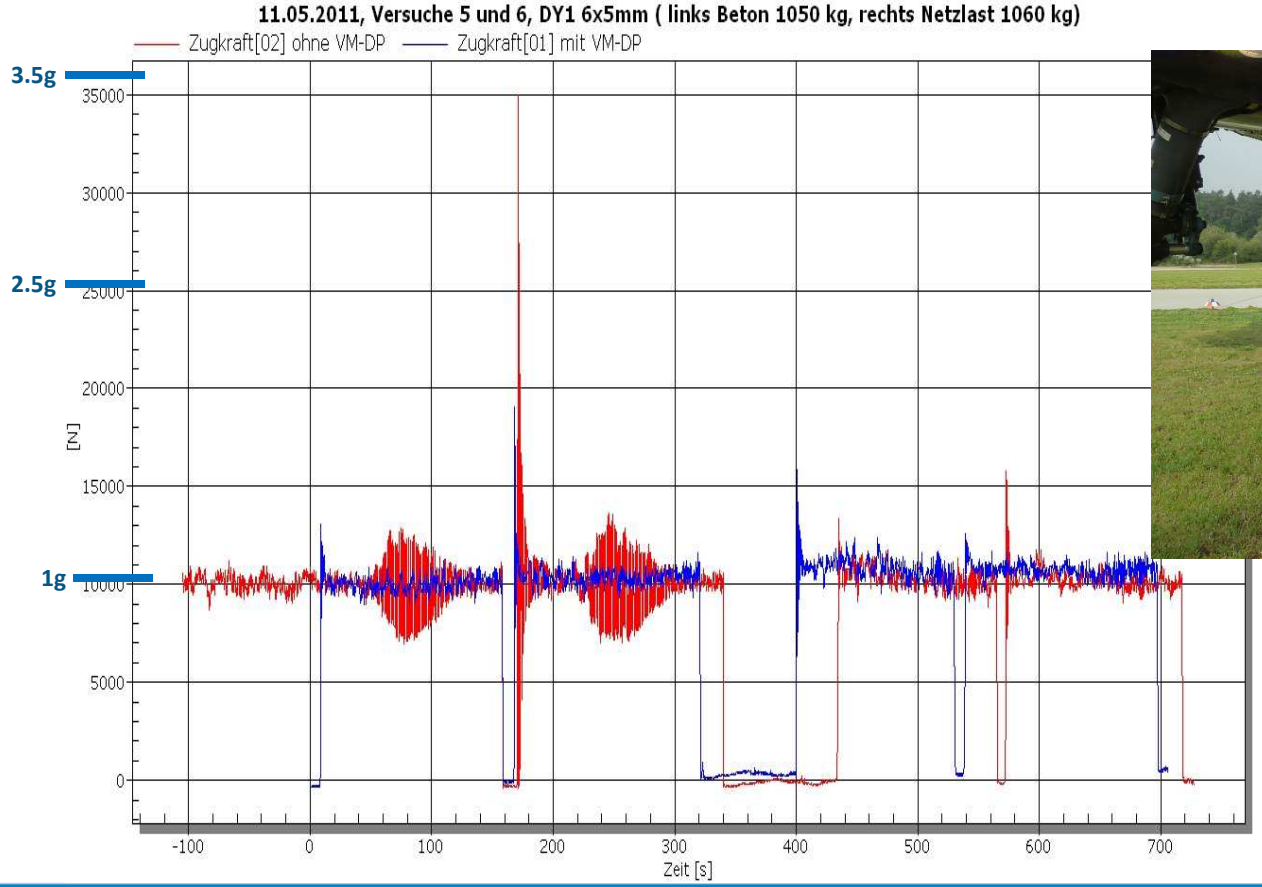
Dynamic Load Magnification at Turns (hoist example)



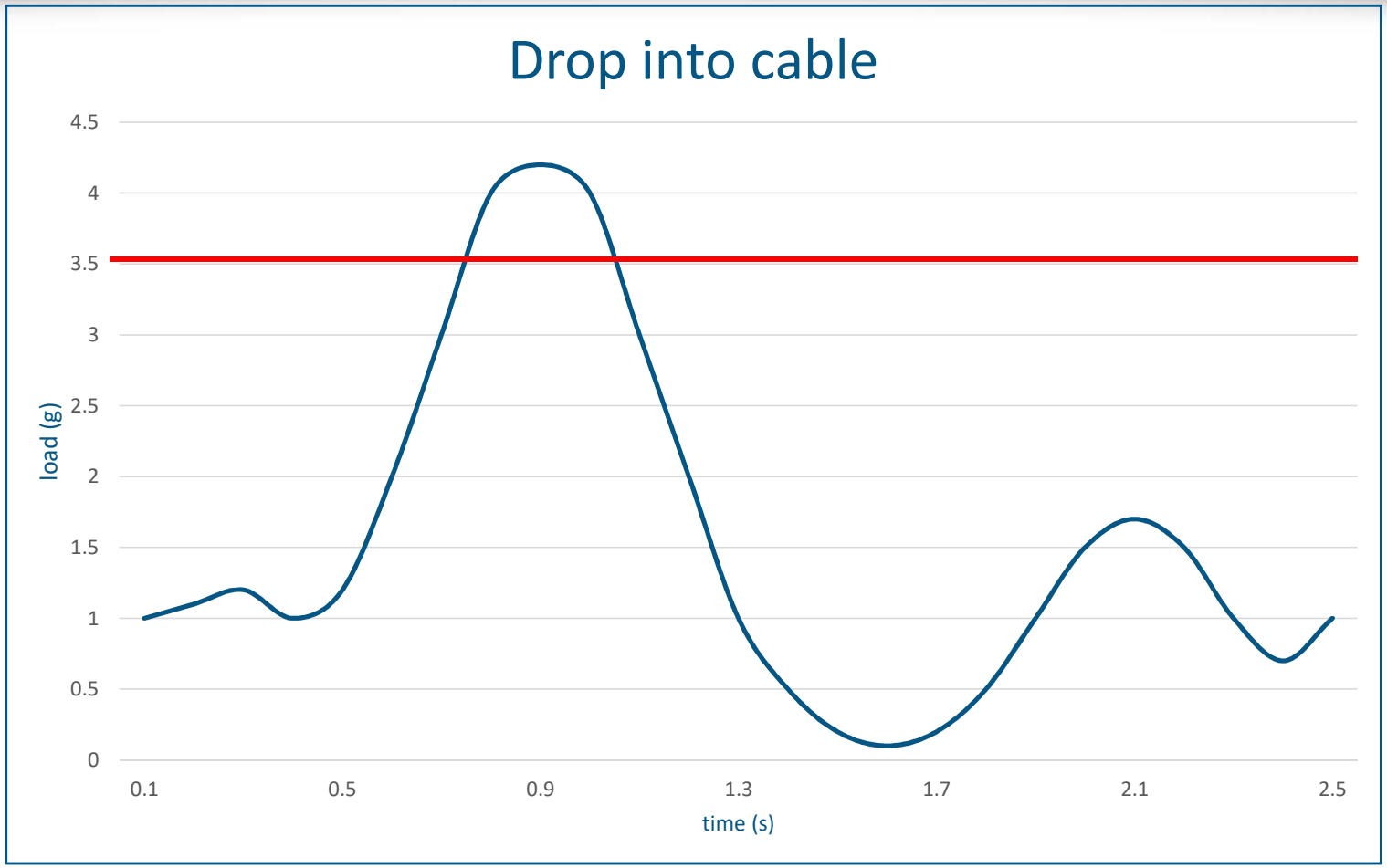
Airspeed	Bank Angle	Hoist Angle	A/C turn radius	Hoist Radius	A/C Nz	Hoist Nz
kts	degrees	degrees	ft	ft	g	G
10	10	15	50	76	1,02	1,04
10	20	59	24	110	1,06	1,92
10	30	77	15	113	1,15	4,36
20	10	11	201	220	1,02	1,02
20	20	28	97	145	1,06	1,14
20	30	53	64	141	1,15	1,66
20	40	70	42	136	1,31	2,88
30	10	10	452	470	1,02	1,02
30	20	23	219	258	1,06	1,09
30	30	40	138	203	1,15	1,31
30	40	58	95	180	1,31	1,88
40	50	65	119	209	1,56	2,32

Dynamic Loads

Loads during gentle manoeuvring



Dynamic Loads



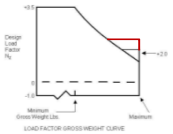
Dynamic Loads

- https://youtu.be/-ym-ZXafoF0?t=120

Load Factor

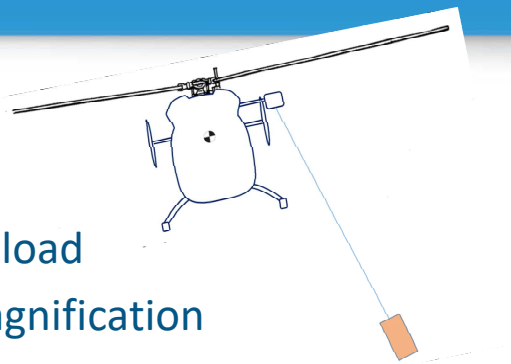
- Requirement CS 27/29.865

$N_{ZW\ MAX}$ = 3.5g or CS 27.337 ← manoeuvring load



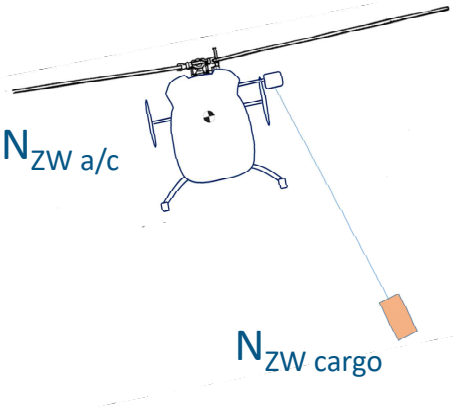
+ dynamic magnification

More relevant to hoist



???

- Flight Test
  - measure $N_{ZW\ a/c}$ and $N_{ZW\ cargo}$
  - dynamic magnification = $N_{ZW\ cargo}$ - $N_{ZW\ a/c}$



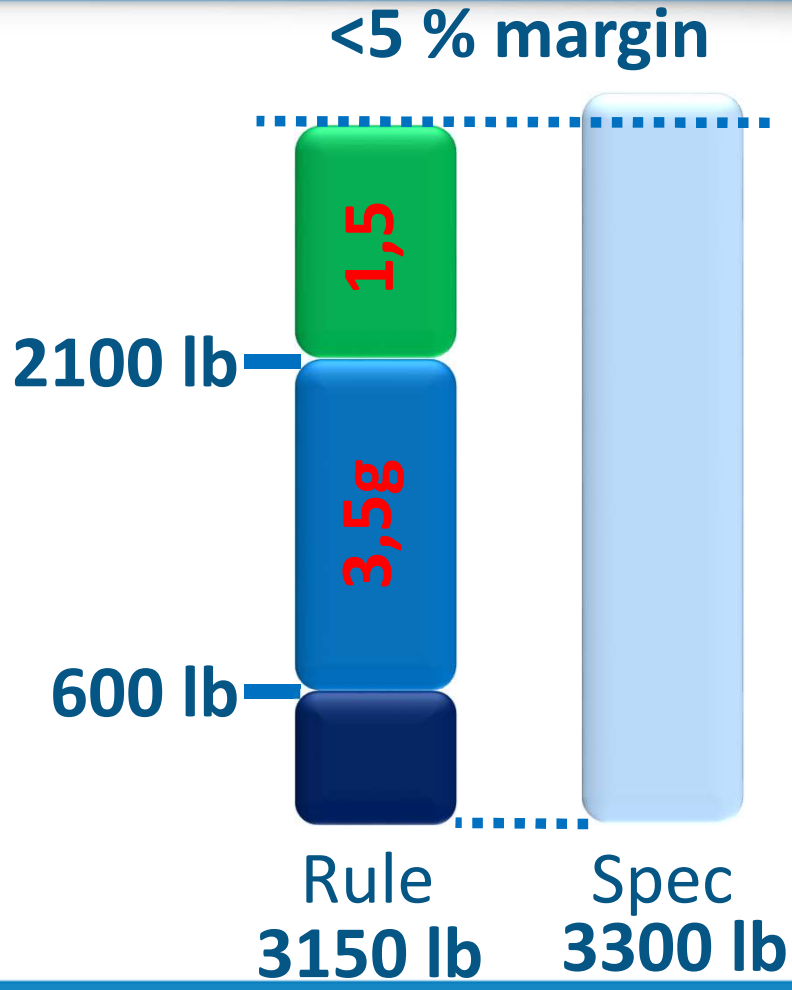
Fatigue for Hoist and HEC

- 27/29.571 for metallic
  27/29.573 for composite
  is applicable
- Load spectrum has to be developed
  - Taking into account different usage
  - Must be validated by flight test
  - Must cover most severe usage

Hoist Usage Spectrum

Current Cable specific – Static Strength

- Cables per MIL-W-83140 (issued 11 April 1969)
- Outside diameter 3/16” = 4.76 mm
- Breaking strength min. 3300 lb

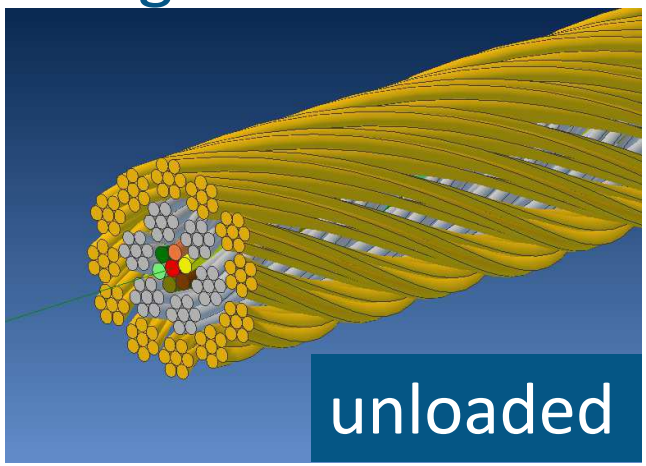


Cable static strength

- Static strength at minimum manufacturing quality
- Take into account the actual installation
- Take into account all allowable / non inspectable damages
- Take into account wear
- Has to withstand ultimate load at the end of the life
- Consider any environmental effects

Cable static strength - unwinding

- Unwinding: Inner core takes more load



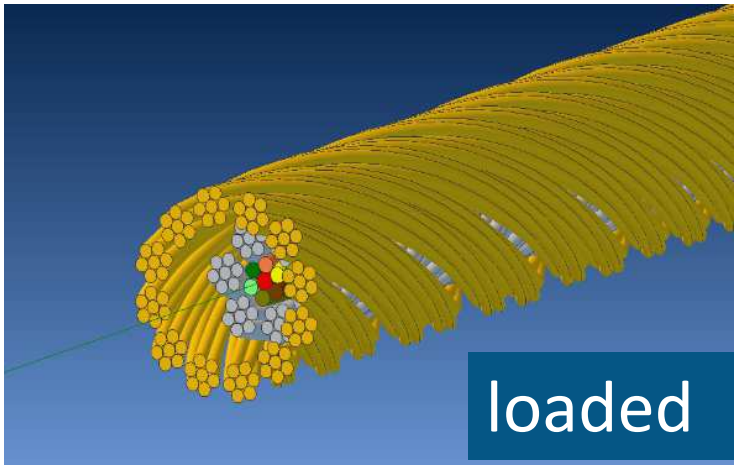


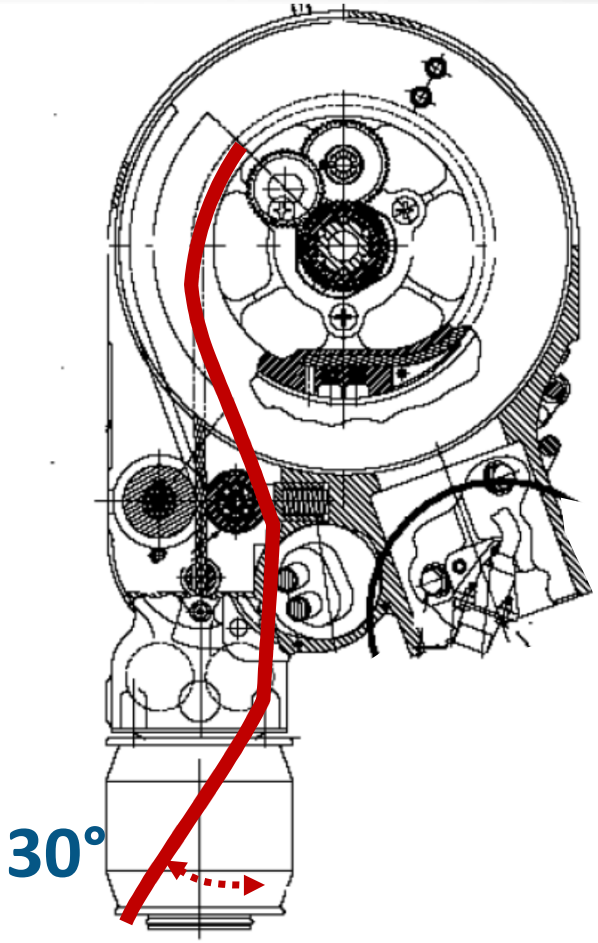
Table 3-5. INFLUENCE OF ROTATION ON ULTIMATE STRENGTH OF 1½-INCH, 18 x 7 NONROTATING WIRE ROPE

Manufacturer	Ultimate Strength Ends Fixed, lbs.	Ultimate Strength One End Free, lbs.	Reduction in Strength, Percent
A	132,800	100,500	24.3
B	121,500	80,000	34.2
C	132,600	97,000	26.9
D	128,400	91,000	29.1

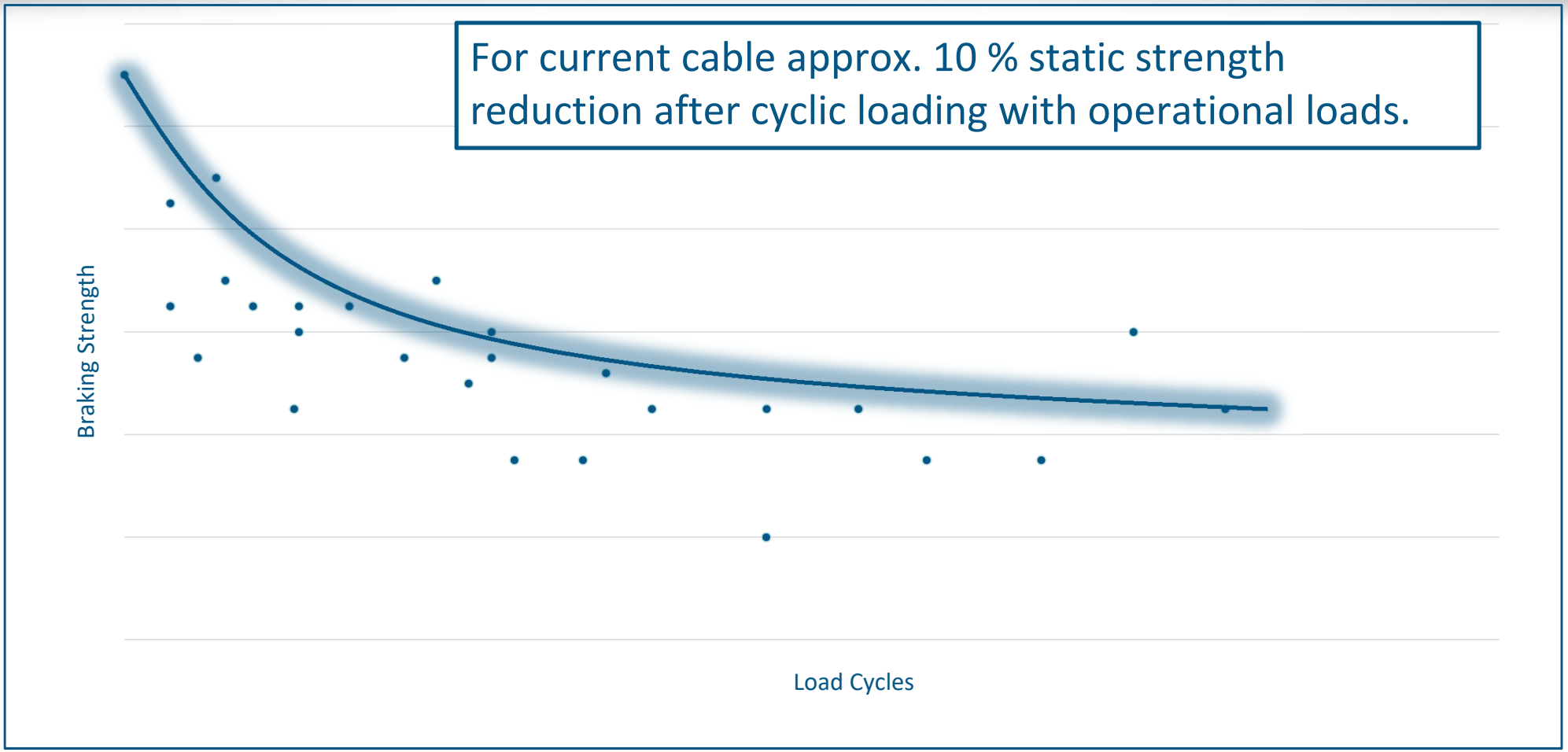
(US Navy wire rope handbook)

Cable static strength – bending

- further strength reduction due to bending
- Depends on the radius of sheave
- Applies already if the cable just touches the sheave
- Approx. 15% for the current hoist design



Cable static strength after cycling



Cable Static strength influencing factors 1/2

- Non-exhaustive list of strength influencing factors
  - Unwinding. If the end of the cable is allowed to swivel the cable unwinds under load. As a result only the inner cable will carry the loads.
  - Bending of the cable due to guidance through pulleys.
  - Normal fatigue (repeated loads).
  - Worn out guide rollers.
  - Lubrication / non lubrication.
  - The cable wires can be welded. This may cause a high accumulation of welding potentially reducing the cable strength and its fatigue properties.

Cable Static strength influencing factors 2/2

- Corrosion
- Flattened areas.
- Abrasion. Spool on multiple layer drums; strand interlocking causing excessive rope abrasion.
- Dynamic load (shock) event.
- Environmental factors
  - Humdity
  - Fluids (oil, hydraulic fluids, fuel, salt water, glycol, cleaning agents, …)
  - Exhaust gases
  - Solar radiation
  - Sand / dust

Cable Fatigue

- The cable has to sustain Ultimate Load at the end of its life
- Include all fatigue types (Bending/Tension/Rotation/…)
- The tested cable has to have minimum manufacturing quality, including all manufacturing flaws or allowable damage
- Assess the inspectability of the fatigue damages (Inner damages are hard to inspect)
- Perform a damage threat assessment

The overall approach is comparable to composite material fatigue substantiation, even for metallic cables

Entanglement

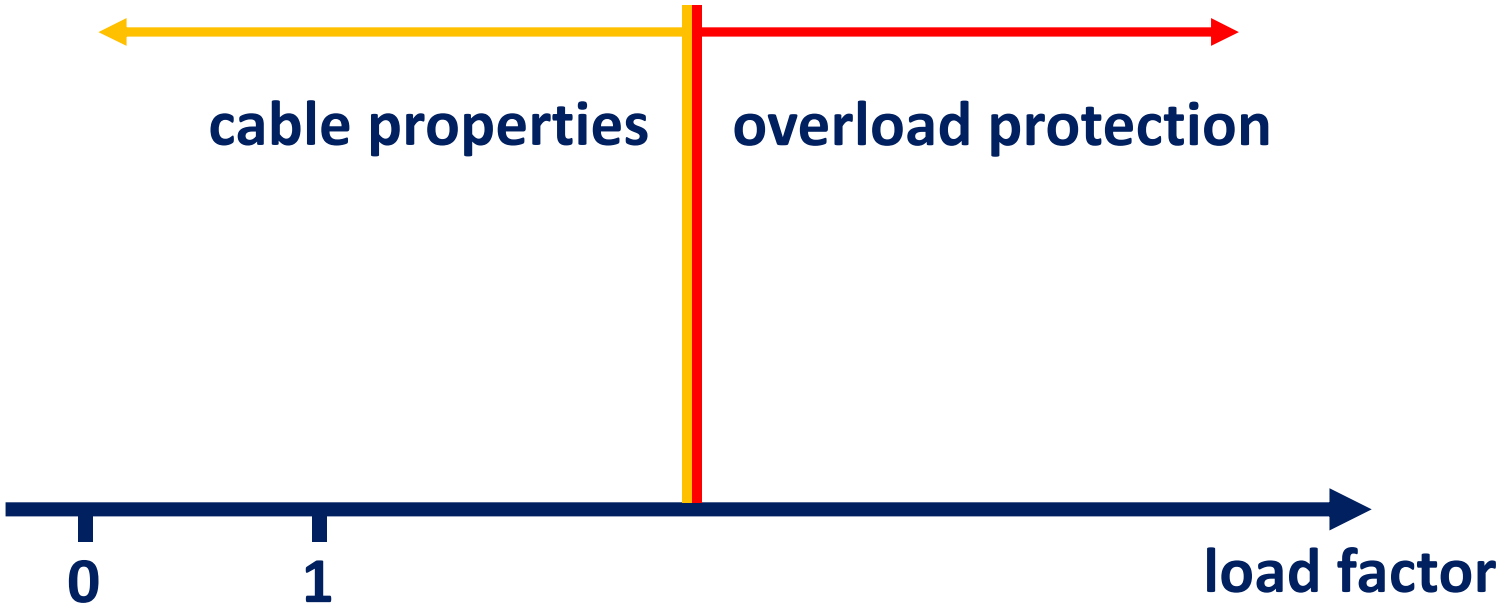
Rebound test – steel cable – 2.5g

Rebound test

Damage at crane due to rebound

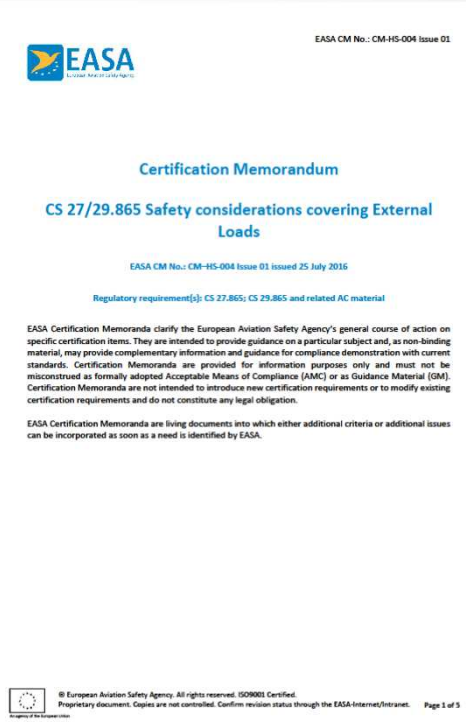
Overload / Rebound

- overload/rebound failure modes



Certification Memo on External Load

- Failure modes to be addressed:
  - overload, e.g. due to entanglement, manoeuvring or shock load,
  - sudden structural failure in overload condition,
  - rebound (also called backlash or spring up) of the cable following rupture.



EASA CM No.: CM-HS-004 Issue 01

EASA

Certification Memorandum

CS 27/29.865 Safety considerations covering External Loads

EASA CM No.: CM-HS-004 Issue 01 issued 25 July 2016

Regulatory requirement(s): CS 27.865; CS 29.865 and related AC material

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EASA Certification Memoranda are living documents into which either additional criteria or additional issues can be incorporated as soon as a need is identified by EASA.

AMC 2 to 27/29.865 PCDS

Personal-carrying device system (PCDS)

A device that has the structural capability and features needed to transport occupants external to the helicopter

Simple

- Personal-carrying device system (PCDS) EN standard under EC Directive 89/686/EEC or Regulation (EU) 2016/425
- Max. 2 Pax ouside cabin / 1 Pax inside cabin
- Not a rigid structure

- For static strength substantiation load factors are given in the AMC
- Fatigue substantiation can be covered by static substantiation for most cases

Complex

- All PCDS that are not simple

- Full compliance static and fatigue tolerance requirements

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