



meridian

Perspectives on Wind Turbine Safety

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Safety first!



Wind Turbines are dangerous!



Fatalities during Feb–July 2017

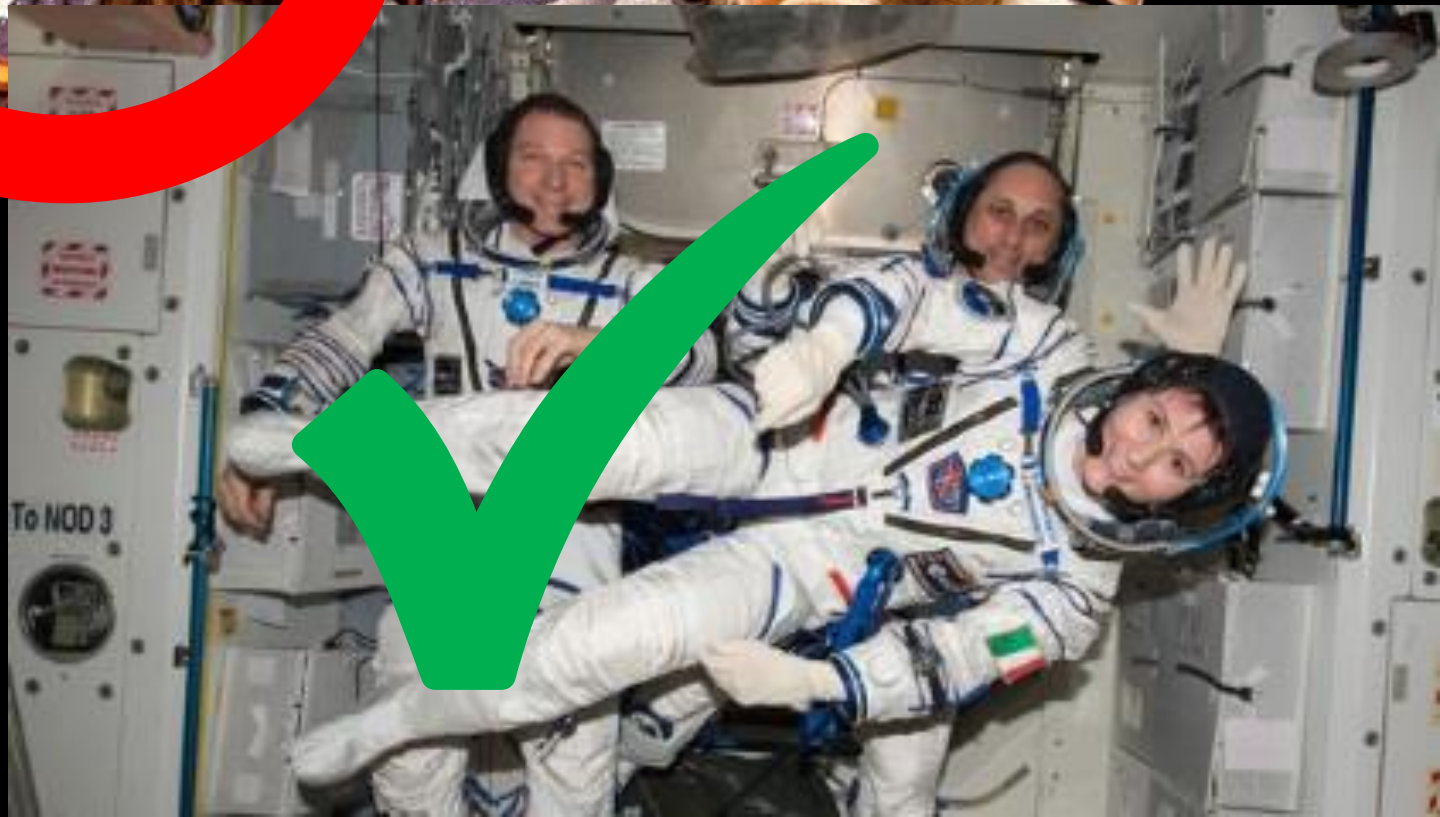
Date	Location	Event
2 Feb 2017	Ramnagar wind farm, India	Contractor electrocuted in substation
15 Mar 2017	Kilgallioch wind farm, Scotland	Contractor fell 5 m from yaw platform
27 Mar 2017	La Bufa wind farm, Mexico	Contractor fell 25 m from tower platform
29 Mar 2017	Whitelee wind farm, Scotland	Maintenance worker fell from nacelle to ground
31 Mar 2017	Rayala wind farm, India	Welding in turbine started a fire
18 Apr 2017	Deerfield wind farm, USA	Mobile crane contacted HV overhead line
3 May 2017	Jamnagar wind farm, India	Mobile crane contacted HV overhead line
8 May 2017	Esbjerg harbour, Denmark	Contractor pinned between blade and trailer
17 Jul 2017	Binhai North H2 (offshore), China	Fire in offshore substation, worker drowned

Fatalities during Feb–July 2017

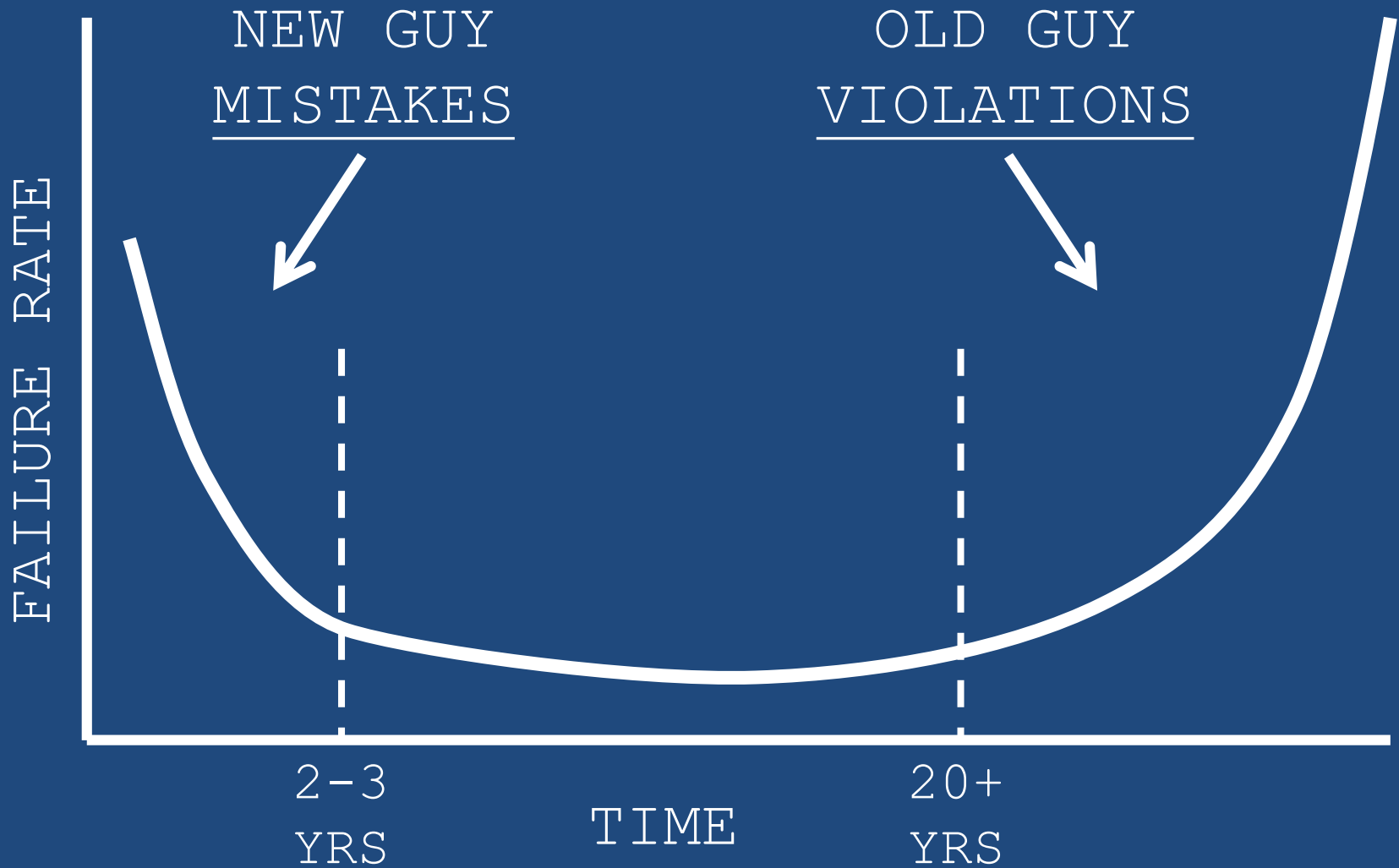
Date	Event
2 Feb 2017	Contractor electrocuted
15 Mar 2017	Contractor fell
27 Mar 2017	Contractor fell
29 Mar 2017	Worker fell
31 Mar 2017	Welding fire
18 Apr 2017	Crane contacted HV
3 May 2017	Crane contacted HV
8 May 2017	Contractor pinned
17 Jul 2017	Offshore substation fire

Key findings:

- Mostly contractors
- Not all in-turbine (substation, cranes, etc)
- Fall protection not applied
- Lock Out procedures not applied
- Hot Work procedures not applied
- General violations of existing procedures
- Unplanned work



BATHTUB CURVE OF HUMAN ERROR



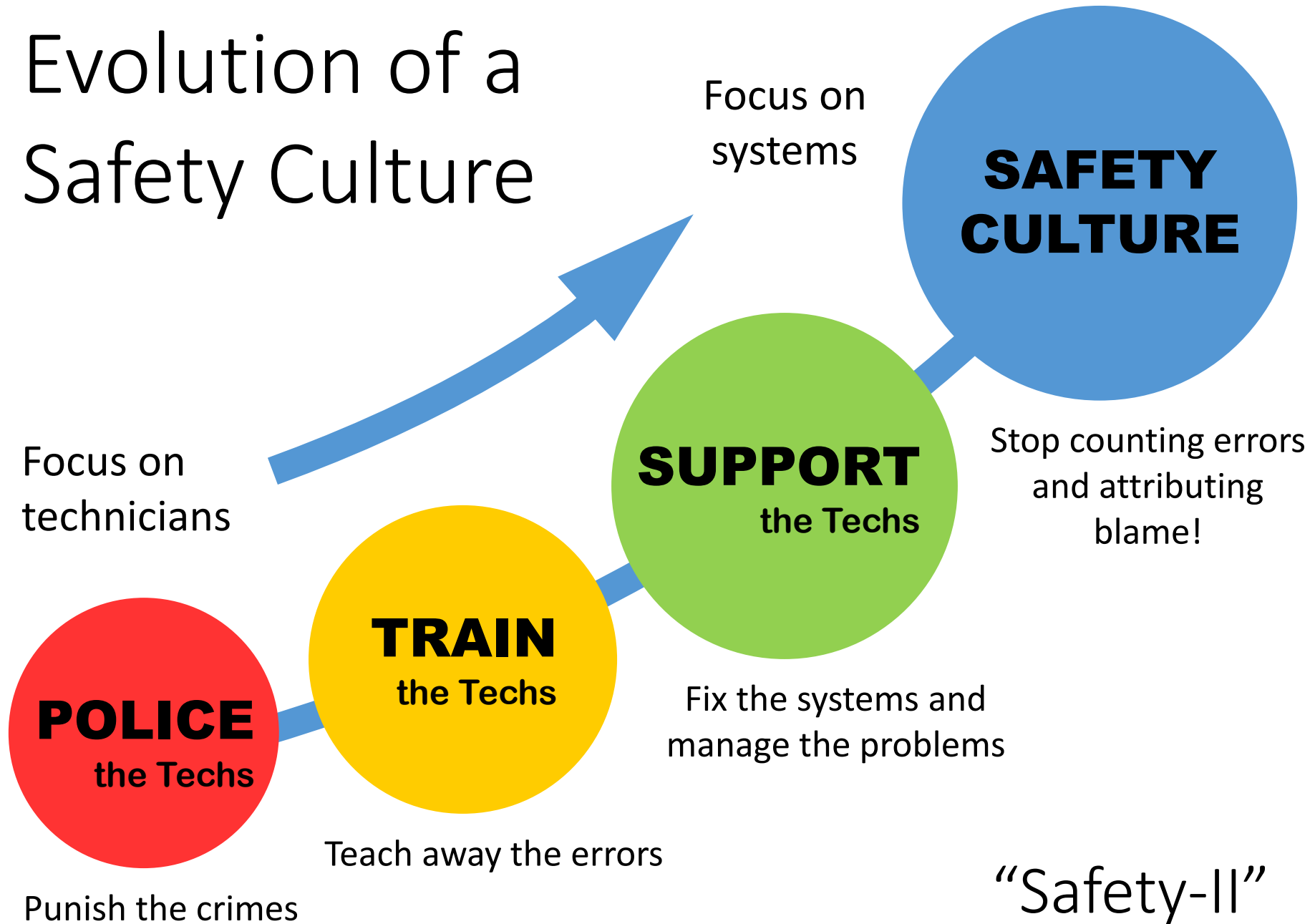
Death of an Elevator Technician



- Wellington-based technician for Otis elevators
- Crushed to death, 2016
- Coroner's inquest, 2018
- Pit switch not engaged (or tripped off)
- **27 years experience, Level 4 service tech**
- **Official procedure** *differed from Actual procedure*



Evolution of a Safety Culture



Our framework: Wind Turbine Safety Rules

To achieve **Safety From The System:**

1. all work in the turbine is **planned work...**
2. following an **Approved Written Procedure...**
3. which lists approved **isolations and safety steps.**

The primary goal is technician safety

Wind Turbine Safety Rules: Docs

JSA Job Safety Analysis

WSSP Worksite Safety Plan

**AWP
(ROP)** Approved Written Procedure
(or Routine Operating Procedure)

WI Work Instructions

Wind Turbine Safety Rules: Docs

JSA

Job Safety Analysis

- About 30 generic JSAs
- Several individual task-based JSAs
- Hazards, Risks, and Control Measures

WSSP

**AWP
(ROP)**

WI

Hazard (the activity/equipment/etc)	Risk (what could happen)	Control measure (eliminate, isolate, minimize)	Risk Factor After Control (Risk = Probability x Consequence)
Skin exposure to hydraulic fluid	<p>Risk Factor After Control (Risk = Probability x Consequence)</p>		
Sudden movement of moving parts	<p>Risk Factor After Control (Risk = Probability x Consequence)</p>		

Wind Turbine Safety Rules: Docs

JSA

Worksite Safety Plan

WSSP

- Toolbox talk, *before* the job
- Summary of Hazards + Controls
- List of related documentation
- Emergency Rescue Plan
- Everyone signs on

**AWP
(ROP)**

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Wind Turbine Safety Rules: Docs



JSA

Worksite Safety Plan

WSSP

AWP
(ROP)

WI

	TUK WSSP 704—Replace yaw motor or yaw gear Te Uku—Siemens 2.3MW-101—Worksite Safety Plan V1.3—Created 2017-05-23—DRAFT	TUK WSSP 704 V1.3
		

Replace yaw motor or yaw gear

Replacement or major work on yaw motors or yaw gear, including application of yaw lock and entry to yaw section as required.

Wind farm location: <i>Te Uku</i>	Turbine type: <i>Siemens 2.3MW-101</i>	Turbine #:	Date:
Task or work order #:		Associated permits:	
Work description:			



A. Turbine Alerts (limitations and restrictions)

<input type="checkbox"/> Request Transfer of Control. Note TOC time.	Accept TOC time:	Return TOC time:
<input type="checkbox"/> Confirm turbine alerts. <i>List any safety-related alerts below or write NONE. Note any isolations already in place.</i>	Asset shutdown time:	Asset restart time:

B. Task-Related Hazards and Controls

Identify hazards that you may encounter or create, on this day, in this turbine, for this work party. Reduce risk by applying effective control measures to eliminate or minimize those hazards.

Hazards and Controls	
<input type="checkbox"/> Assurances, SM-EI permits	<i>If assurance received, acknowledge isolations in 'Alerts' box above. Note associated permit number.</i>
<input type="checkbox"/> Safety from the System	<i>Follow Approved Written Procedure—Keep signature checkpoints up to date.</i>
<input type="checkbox"/> General PPE requirements	<i>Required at all times: Helmet, safety boots. Required as appropriate: Gloves, eye protection, arm and face protection.</i>
<input type="checkbox"/> Rings, Jewellery, Watches, Long hair, Loose clothing	<i>Remove rings/jewellery/watches (or where not practicable, cover them) to ensure they cannot cause harm through entanglement with equipment or ladders, or by contact with live electrical equipment. Tie back long hair and loose clothing.</i>
<input type="checkbox"/> Daily/pre-use checks	<i>Check turbine log book, fire extinguishers, service lift, ladders + safety wire, crane/chain hoist, lifting gear.</i>
<input type="checkbox"/> Public safety, farm operations, other people on site	<i>Site hazard boards, 'WhosOnLocation' hazard alerts, Daily/Weekly Meetings. Be aware of others on site.</i>
<input type="checkbox"/> Visitor inductions, Contractor assessments (for anyone unfamiliar with the turbine)	<i>Direct supervision required. Use visitor induction TUK WI 002 or contractor assessment TUK WI 002A.</i>
<input type="checkbox"/> Driving	<i>Drive to the conditions. Park safely facing into the wind. Pre-use safety check for your vehicle.</i>
<input type="checkbox"/> Noise	<i>Use hearing protection at turbine start/stop and as appropriate (e.g. use of power tools).</i>
<input type="checkbox"/> Manual handling, posture	<i>Use lifting aids. Plan team lifts. Avoid poor posture. Perform periodic stretches.</i>
<input type="checkbox"/> Trips, Slips and Falls	<i>Take care in and around the work site. Clean up as you go.</i>

	TUK WSSP 704—Replace yaw motor or yaw gear Te Uku—Siemens 2.3MW-101—Worksite Safety Plan V1.3—Created 2017-05-23—DRAFT	TUK WSSP 704 V1.3
		

Working at height

- Use safety harness and fall arrest system including slider, lanyards.

Service lift

- Perform pre-use checks before use – Trained and competent personnel only to operate service lift.

Objects falling from height

- Keep clear of potential drop zone. Use tool lanyards. Wear appropriate PPE.
- Identify 15 m drop zone around turbine using cones/tape/signage, or other means.

Lifting operations

- Pre-use checks. Trained and competent personnel only to operate crane/hoist or rig loads. Identify drop zone.

Mobile plant and equipment

- Ensure good comms between operator and safety observers. Check ground conditions.
- Conduct pre-use checks. Work within safe working loads. Follow a lifting plan.

Rotating plant, entanglement, mechanical hazards

- Observe wind speed limits. Apply mechanical isolations. Be aware of potential pinch/crush hazards.
- Hub entry—Be aware of risk of unexpected pitching in hub.
- Yaw lock—Isolate power to yaw motors at all times while yaw lock is in place.
- Yaw entry—Test E-stop in yaw space before any other work activity. If restoring yaw system while a person is in the yaw space, limited to visual inspection only.

Hydraulics

- Do not touch or keep your hands close to hoses or hydraulic fittings under pressure.
- Release stored hydraulic energy before working on hydraulics.
- Safety glasses are required whenever you are working on hydraulics.

Chemical hazards, spills

- Review SDS sheets for chemicals (oils, grease, etc). Use appropriate PPE (e.g. gloves, mask). Use spill kits.

Fire hazards

- Sweep and clean up all combustibles. Take extra care in dry/windy conditions. Check rural fire hazard level.
- Hot work permit + fire watch required for hot work. Visual check of fire extinguishers, report any defects.

Electrical Supplies

- Isolate and de-energize. Lock and Tag, then Prove—Test—Prove before touch.

Prescribed electrical work (PEW)

- Maintenance of electrical appliances. Construction or maintenance of works (i.e. fittings used for electricity generation).
- Connection or disconnection of works, electrical installations, or appliances—other than by a plug & socket.
- Testing, certification, inspection, or supervision of the work described above.
- Only trained and competent personnel may perform prescribed electrical work.

Arc Flash (turbine main breaker +A12-Q1, auxiliary breaker +A12-Q2)

- Where possible, operate main breaker from over 3.0 m away – Isolate turbine before operating aux breaker.
- Otherwise wear arc-rated PPE (minimum 25 cal/cm² = Category 3) to operate main breaker or aux breaker.

Work in 'At Risk Areas' (any space with hindrance to rescue, or which may potentially become a confined space)

- Rescue plan. Work in pairs. Carry gas monitors.

Confined Space Entry

- Confined space entry permit + procedures. Confined space training. Rescue plan. Use gas monitors.

Fault-related hazards

- Consider whether the type of fault may result in special hazards.
- Yaw error—if there is a yaw error, watch out for possible sharp pieces or exposed wires in the nacelle.

C. Resources

List task-related safety resources (PPE, safety equipment) and critical task-related tools.

- General PPE, Working at Height equipment—As appropriate to the work task.
- Personal LOTO equipment—As required.
- First aid kit—Bring one first aid kit into the turbine or to the work site.
- Insulated and calibrated electrical tools, PPE—Used during safe electrical work procedures.
- Gas monitor—Mandatory for confined space entry or when working on accumulators in the hub.
- Replacement kit for yaw gears or yaw motors—See work instruction for full list of tools.

Wind Turbine Safety Rules: Docs

JSA

WSSP

**AWP
(ROP)**

WI

Worksite Safety Plan

<input type="checkbox"/>	Arc Flash (turbine main breaker +A12-Q1, auxiliary breaker +A12-Q2) <ul style="list-style-type: none">• Where possible, operate main breaker from over 3.0 m away – Isolate turbine before operating aux breaker.• Otherwise wear arc-rated PPE (minimum 25 cal/cm² = Category 3) to operate main breaker or aux breaker.
<input type="checkbox"/>	Work in 'At Risk Areas' (any space with hindrance to rescue, or which may potentially become a confined space) <ul style="list-style-type: none">• Rescue plan. Work in pairs. Carry gas monitors.
<input type="checkbox"/>	Confined Space Entry <ul style="list-style-type: none">• Confined space entry permit + procedures. Confined space training. Rescue plan. Use gas monitors.
<input type="checkbox"/>	Fault-related hazards <ul style="list-style-type: none">• Consider whether the type of fault may result in special hazards.• Yaw error—If there is a yaw error, watch out for possible sharp pieces or exposed wires in the nacelle.
<input type="checkbox"/>	
<input type="checkbox"/>	
<input type="checkbox"/>	
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Task-specific content is highlighted in blue

Wind Turbine Safety Rules: Docs

JSA

Approved Written Procedure

- Safety checklist – *during* the job
- Isolations and safety steps (only)
- Includes regulatory requirements, like pre-use checks

WSSP

**AWP
(ROP)**

Routine Operating Procedure

- No isolations, just a few safety steps
- General work only

WI

Wind Turbine Safety Rules: Docs

JSA

WSSP

**AWP
(ROP)**

WI

Approved Written Procedure

Hub entry

Enter the hub using At Risk Area rules. If the task or working conditions may create an unsafe atmosphere (e.g. fumes, work on nitrogen accumulators) then use a different AWP which includes a confined space entry permit.

Wind farm: White Hill	Turbine #:	Asset shutdown time:	Asset restart time:
Turbine type: Vestas V80-2.0MW wind turbine		WTG Work Order #:	

1.0 Permit authority—Sign on to AWP or transfer authority to another Technician

Authorised Technician name:	Sign on:	Date:

2.0 Remove from service

2.1 If isolations are already in place, note Form 4005 number here.	Form 4005 serial number	
2.2 Request Transfer of Control—Confirm turbine restrictions	<input type="checkbox"/>	
2.3 Set Service/Remote Key to 'SERVICE'.	Signature	Time
2.4 Set turbine to PAUSE—Remove key.	<input type="checkbox"/>	
2.5 Check windspeed (10 min average)—Windspeed:.....	<input type="checkbox"/>	
2.6 Turn OFF: top assembly cooling, offline oil filter, top ventilator.	<input type="checkbox"/>	

3.0 Service lift

3.1 Turn ON: lift power supply.	<input type="checkbox"/>	
3.2 Perform pre-use checks for service lift.	<input type="checkbox"/>	

Wind Turbine Safety Rules: Docs

JSA

WSSP

**AWP
(ROP)**

WI

Approved Written Procedure

6.0 Apply hydraulic rotor locks

6.1	Stop the shaft/hub at appropriate angle—Set turbine to PAUSE. Pitch blades near 87° stop—Release/apply brake to align holes.	<input type="checkbox"/>	
6.2	Apply hydraulic rotor locks Both pins extended—Handle in lock position—Apply Tag	Signature	Time
6.3	Pitch blades to 87° full stop position—Hit E-stop to apply brake. <i>Later, reset E-stop/brake as required for the work task.</i>	<input type="checkbox"/>	

ROMP 7.0 Restoration of Motive Power—hydraulic rotor locks **ROMP**

As required, temporarily remove isolations—Section R7.

8.0 Apply manual rotor lock *(if required)*

8.1	Apply manual rotor lock—Apply Tag	Signature	Time
8.2	Pitch blades to 87° full stop position—Hit E-stop to apply brake.	<input type="checkbox"/>	

9.0 Enter hub

9.1	Discuss rescue plan—A rescue trained person remains nearby.	<input type="checkbox"/>	
9.2	Push E-stop before entering hub. <i>Later, reset E-stop as required</i>	<input type="checkbox"/>	
9.3	Apply isolation: Open all THREE blade leak valves (5V1). Drain pressure in pitch system—Apply Tags	Signature	Time

ROMP 10.0 Restoration of Motive Power—blade valves (5V1) **ROMP**

As required, temporarily remove isolations—Section R10.

11.0 Perform work in the hub

Perform work in the hub according to work instructions.

Wind Turbine Safety Rules: Docs

JSA

Work instructions

WSSP

**AWP
(ROP)**

WI

- How to actually *do* the job
- Also charts, diagrams, other notes
- Keep this information out of the other formal documentation
- Encourage techs to help build up this body of IP.

Wind Turbine Safety Rules: Docs

JSA

WSSP

**AWP
(ROP)**

WI

Work instructions

- N.11
- Reset E-stop on chain hoist pendant controller.
 - Operate the chain block using the pendant controller.
 - Before lowering the chain to the ground, test the pendant control buttons for down, up and stop.

If the 'up' control is malfunctioning, then it is too late to discover this when 70m of chain has already been lowered to the ground.



- N.12 After use:
- Switch off socket and unplug before putting away chain hoist.
 - After use, place the chain block and the crane in their holders.
 - Park the crane so that it is supported when hydraulic pressure is released.
 - Ensure that the hoist cables are unplugged and put away tidy and not tangled.



- N.13
- **Note that the chain hoist cannot sustain constant use at full load.**
 - If you are transferring multiple heavy loads from ground level to the nacelle, allow the chain hoist to rest and cool down for a few minutes between loads.

Wind Turbine Safety Rules: Docs

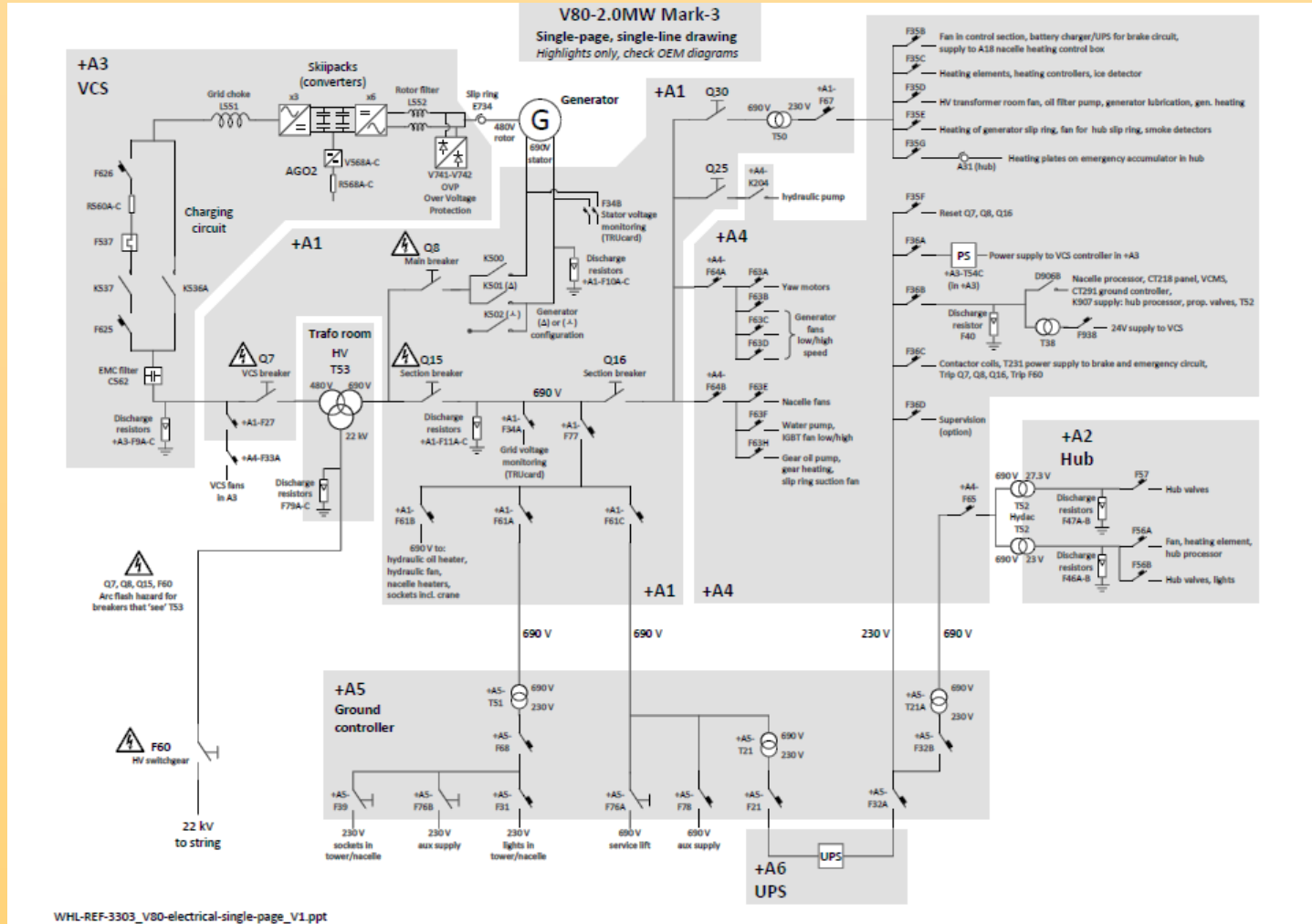
Work instructions

JSA

WSSP

**AWP
(ROP)**

WI



Wind Turbine Safety Rules: Docs

JSA

Plus:

WSSP

- **Meridian's WTSR Rules**
(our booklet of the actual rules)

AWP
(ROP)

- **Management Instructions**
(guidance for odd situations)

WI

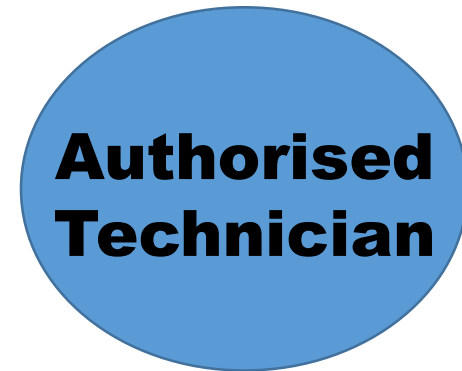
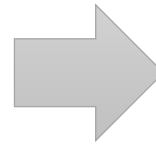
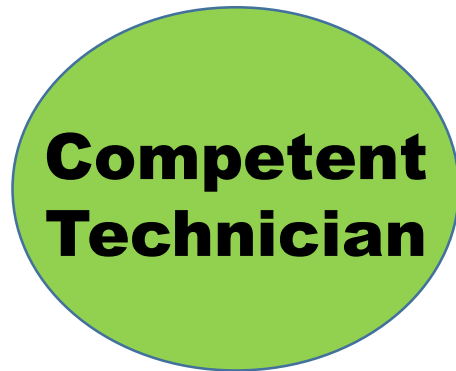
Paperwork



Wind Turbine Safety Rules: Roles



Wind Turbine Safety Rules: Roles



“Basic permit competency”

Trained in:

- safe turbine operation
- isolations
- boundaries of work

Routine Operating Procedure
(general work, no isolations)

“Advanced permit competency”

Demonstrated competency in:

- the WTSR rules
- How to handle situations where the rules break down

Approved Written Procedure
(apply LOTO isolations)

...this is NOT technical competency

But what about...

- Doesn't having a script of isolations *dumb it down*?



DISAPPROVAL

You'll know it when you see it.

But what about...

- Doesn't having a script of isolations *dumb it down*?

NO!



But what about...

- Doesn't having a script of isolations *dumb it down*?
- What if there's no AWP written for this job yet?



DISAPPROVAL

You'll know it when you see it.

But what about...

- Doesn't having a script of isolations *dumb it down*?
- What if there's no AWP written for this job yet?

Then the
job waits

We've got people
working on it...



DISAPPROVAL

You'll know it when you see it.

But what about...

- Doesn't having a script of isolations *dumb it down*?
- What if there's no AWP written for this job yet?
- What if, mid-job, I see something else to fix?
Do I just leave it?

YES

But what about...

- Doesn't having a script of isolations *dumb it down*?
- What if there's no AWP written for this job yet?
- What if, mid-job, I see something else to fix?
Do I just leave it?

If it's dangerous, lock it out.
Otherwise, just raise a new work order.



DISAPPROVAL

You'll know it when you see it.

But what about...

- Doesn't having a script of isolations *dumb it down*?
- What if there's no AWP written for this job yet?
- What if, mid-job, I see something else to fix?
Do I just leave it?
- Isn't this less efficient?

YES
(we know)

But what about...

- Doesn't having a script of isolations *dumb it down*?
- What if there's no AWP written for this job yet?
- What if, mid-job, I see something else to fix?
Do I just leave it?
- Isn't this less efficient?

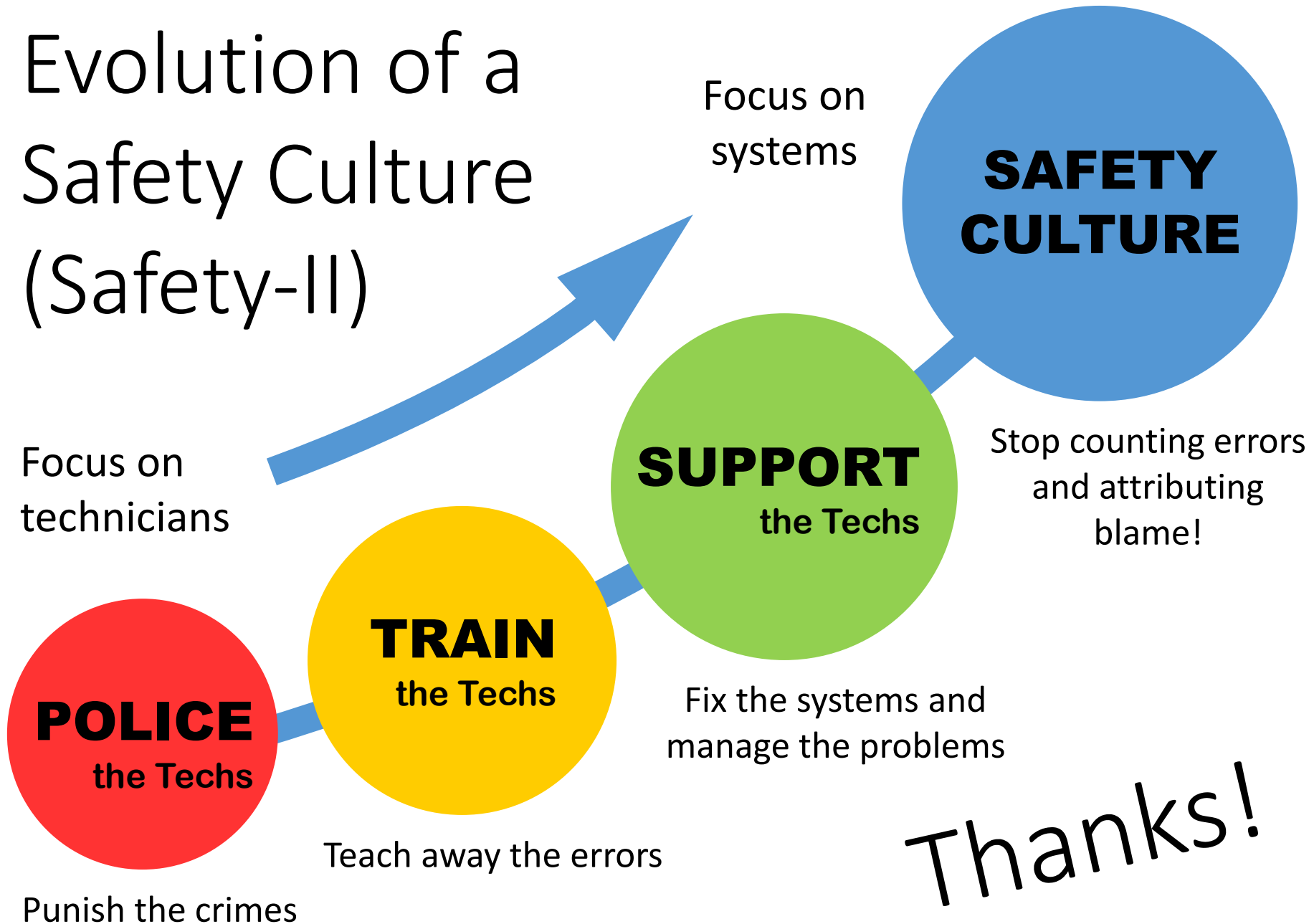
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1. all work in the turbine is **planned work...**
2. following an **Approved Written Procedure...**
3. which lists approved **isolations and safety steps.**

The primary goal is technician safety

Evolution of a Safety Culture (Safety-II)



Thanks!