

## NOPSEMA Investigation – Prelude FLNG – Report

### Investigation details

<b>Facility:</b>	Prelude FLNG
<b>Operator:</b>	Shell Australia Pty Ltd
<b>Date investigation commenced:</b>	9 December 2021
<b>Lead Investigator:</b>	██████████
<b>Investigation team:</b>	██████████
<b>Investigation number:</b>	IVT11026

### Report distribution

Position	Company
Records management	NOPSEMA
	Shell Australia Pty Ltd

### Revision status

Rev	Date	Description	Prepared by	Approved by
A	17 Dec 2021	Internal draft	██████████	██████████
B	20 Dec 2021	Draft for discussion with duty holders	██████████	██████████
0	23 Dec 2021	Final	██████████	██████████

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## Background

### Notifications

At 02:14 on 3 December 2021 NOPSEMA received initial verbal notification (NTF10891) of the following event on the Prelude FLNG facility that had occurred at 22:38 on 2 December:

*“Total power loss on the Prelude FLNG. Alarm and muster, all personnel accounted for . . . 1st EDG started within 1 hour of power loss. 2nd EDG started within 3 hours of power loss”.*

Subsequently, the initial written report from Shell was submitted to NOPSEMA, on 6 December 2021. The details provided in the initial report were as follows:

*“On 2nd December 2021 at approximately 2240, smoke was detected in Uninterrupted Power Supply (UPS) 214 room. The presence of smoke was confirmed to be visible inside the room. The facility was mustered, and all personnel accounted for within 11 minutes. It was confirmed that there was no impact to surrounding rooms, above, below and either side and that all detection and management systems in the UPS room functioned as expected. The power to the room was isolated and the room barricaded.*

*An Emergency Shutdown (ESD), ESD1 was manually initiated, however during this process, an ESD0 type event occurred, and all power was lost. Self-contained/ battery operated emergency lighting remained operational. The facility remained at muster until approximately 8am on the 3rd December, as the team worked to reinstate power and essential services.*

*Following loss of power, initial communications with the facility was via marine VHF relay through Infield Support Vessels (ISV) and later via satellite phones.*

*Over the course of the 3rd-5th December, interrupted power supply was experienced, leading to a decision to down-man the facility from 293 to 148 Personnel on Board (POB) via ISV and helicopter operations on the 4-5th December”.*

On 7 December a second notification by the operator (NTF10902) for this event was received by NOPSEMA for an occurrence that was directly related to the notification on 3 December. The information received at the time related to the Essential Diesel Generators (EDG):

*“EDG10 and EDG30 were synchronized onto the main board. Immediately following the starting of EDG20 and synchronizing onto the main board, a power trip occurred. A General Alarm and muster were initiated. The Emergency Power Generator was started within 5 minutes and muster completed within 11 minutes. EDG10 was returned within 33 minutes and EDG30 returned within 62 minutes, with all essential services now returned. The Emergency Power Generator has been returned to stand-by and EDG20 will not be restarted until fault is diagnosed and repaired. [REDACTED] backed up the notification with further detail of the event”.*

A third notification by the operator (NTF10920) to NOPSEMA on 14 December (i.e. subsequent to the NOPSEMA offshore investigation on 9 & 10 December) that addressed events over the period of 3 to 6 December stated:

*“During ongoing power outages on the Prelude FLNG, where limited HVAC facilities were available and activities were being undertaken to respond to the power outage, four persons experienced heat related illnesses requiring medical treatment”.*

A fourth related notification (NTF 10916) was received on 14 December. This notification originated as an anonymous complaint by telephone to the NOPSEMA switchboard which was transferred to the Duty Inspector. Follow-up on this provided information was included into the wider NOPSEMA investigation scope:

*“[REDACTED] made a complaint . . . advise that the operator was not acting on the results of fatigue assessments being conducted on personnel who have been on the facility since the UPS fire . . . Medics onboard have found personnel that are fatigued/burnt out, which has been passed onto the operator who has failed to act on this information. It was also stated that, 1) Operator is more concerned about restarting production than worker health. 2) Medics are contractors and can only do so much”.*

In addition to the incidents and notifications associated with this investigation, the inspectors note analogous historical power outages that occurred at the facility on 2 and 3 February 2020, which resulted in loss of hotel services and partial demobilisation of the facility. These loss of power events were the subject of NOPSEMA inspection 2156.

### **NOPSEMA Offshore Investigation**

From 3 December, the NOPSEMA focal point inspector for Prelude FLNG commenced an investigation and was in daily (or more frequent) contact with Shell onshore management to receive updates of the emergency situation offshore caused by the loss of power and consequential impact on habitation and working conditions for personnel, and the activities underway to respond and recover.

On 6 December the continuing unreliable power was determined to represent an ongoing impact to the health and safety of personnel on the facility. As a result, NOPSEMA decided to conduct an offshore investigation. The inspectors were then mobilised to the facility on 9 December 2021 as the first available opportunity, returning ashore on 10 December.

This report presents the inspectors' findings for the investigation of the circumstances of the immediate events of the power outage on 2 December 2021 and the resulting notifications and complaint. The root causes of the events are not the subject of this investigation, and it is expected that further investigations may occur as a result of the findings of this report.

## **Investigation Objectives**

NOPSEMA initiated this investigation to:

- Collect first-hand information to quickly understand the extent, consequence and immediate risks associated with the incident/circumstances
- Confirm the incident is under control
- Determine if there is an appropriate plan in place to:
  - Conduct a proper internal investigation
  - Manage the immediate risks
  - Return to compliance
- Determine if there is an immediate or significant threat requiring intervention by NOPSEMA

- Through the process of gathering information/intelligence, consider whether an offence may have occurred which could require further escalation to make that determination.

## Conclusions

Note: These are the inspectors' conclusions based on their findings during the offshore inspection, which ended on 10 December 2021, and requested documentation provided by Shell immediately thereafter. It is acknowledged that Shell has continued to investigate the initial and subsequent events that are the subject of NOPSEMA's investigation. This report and the inspectors' conclusions should be read in that context.

1.	<b>The immediate risks to personnel resulting from the power outage on 2 December were being appropriately managed and the incident was under control at the time of the offshore investigation (9 – 10 December).</b>
2.	<b>The Prelude FLNG facility, which requires control of the temperatures and pressures of hydrocarbon storage tanks, requires an immediate and sustained effort to restore power and essential safety functions if they are lost.</b>
3.	<p><b>The robustness of the facility power system on the Prelude FLNG facility is inadequately understood, including failure mechanisms, interdependency and recovery. The impact of these issues directly resulted in extended timeframes of unstable power. This directly impacted:</b></p> <ul style="list-style-type: none"> <li>• <b>Emergency response, operation of safety critical equipment (e.g. communications), evacuation of non-essential personnel</b></li> <li>• <b>Habitability of the facility for the personnel on board (293 at the time of the event)</b></li> <li>• <b>Demands of process equipment required to effectively manage the LNG inventory e.g. flare management and temperature management of the sub-structure.</b></li> </ul> <p><b>As a result, unless potential failures of critical systems including hotel services and safety critical equipment, are mitigated, the risk from these hazards is not ALARP.</b></p>
4.	<p><b>A Shell internal investigation is planned to determine the cause(s) of the power system issues that lead to this incident. However, the draft investigation scope provided did not plan to assess all of the issues associated with the incident to ensure the immediate risks during a future similar incident are identified and recommendations are made to mitigate them.</b></p> <p><b>The inspectors note that at the time of the investigation, planning for future investigations into the incident was in early stages. Subsequently, Shell has advised NOPSEMA that multiple reviews will be completed to ensure all associated risks are investigated and mitigated.</b></p>
5.	<b>At the time of writing this report, the operator was planning to return to normal operation, after assurance activities are completed adequately.</b>
6.	<b>At the time of writing this report, the inspectors concluded that until power to safety critical equipment is made reliable and robust, the operator should not proceed to restart the facility beyond operations required to ensure safety and stability of the facility.</b>

7.	<b>The constrained timeline of this initial investigation did not allow the inspectors to consider whether any offence against the OPGGSA had occurred. This may be considered further in due course.</b>
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NOPSEMA expects Shell Australia Pty Ltd to consider these findings and conclusions and undertake sufficient action of their own to both fully understand the issues presented and to take action to reduce the risks and impacts to ALARP and come back into compliance with their duties under the *Offshore Petroleum and Greenhouse Gas Storage Act 2006* (OPGGSA) and/or the requirements of relevant permissioning document(s).

## Inspectors Recommendations

The investigation team recommends that:

- NOPSEMA considers whether enforcement is justified to ensure the Prelude facility does not restart before power systems (for safety critical equipment) are assured in the event of main power generation shutdown
- NOPSEMA considers further investigations:
  - Into the broader issues related to this event e.g. robustness of power systems, and adequacy of emergency response
  - To determine whether any offence against the OPGGSA has occurred.
- The NOPSEMA focal point inspector maintains regular contact with the operator's team to:
  - Keep abreast of the situation on the facility as the recovery of this incident progresses
  - Monitor operator's response to conclusions to ensure that risks related to future analogous events and consequent response activities are reduced to As Low as Reasonably Practicable (ALARP).

## Summary of findings

### General

At the time of this offshore inspection the full details of the originating smoke alarm incident and ensuing power system instability(s) were under investigation by the operator and were yet to be established. At this time, unknown information included:

- Root cause of the fire in the UPS
- Exact timeline of subsequent events that occurred
- Root causes of other subsequent failures and trips.

As a result, the inspectors were unable to assess the technical facts and evidence related to the originating incident. Instead, the inspectors focussed on the objectives of this investigation using information provided from interviews of personnel at the facility. However, where available, the inspectors reviewed documentary evidence to inform the findings provided in this section.



## Findings against objectives

### Collect and confirm information to quickly understand the consequence and immediate risks of the incident/circumstance AND confirm that the incident is under control

At the time of the offshore investigation the operator presented a draft timeline of events that occurred after the initial loss of power on 2 December 2021. The timeline of events was built up in stages from various sources including: Emergency Response Centre (ERC) logs, handwritten Central Control Room (CCR) logs, personal accounts [REDACTED] [REDACTED]).

Power failures caused shutdown of the following systems, however, where it has been available data from these systems was used to construct the timeline: Distributed Control System (DCS), Instrumented Protective System (IPS) and historian data from the EDGs.

The operator pointed out that the timeline provided to inspectors (Appendix A) was still in development and would require significant additional input from additional data sources such as (but not limited to) the Electrical Network Monitoring and Control System (ENMCS) logs, UPS logs and ABB switchboard logs.

Key events in the timeline have been listed in the table below. The full draft timeline, as at 10 December 2021, is presented in Appendix A of this report.

Summary Date/Time and Event Description
2/12/2021 22:25: ER-3.230V UPS UP-214V03 Inverter failure alarm.
2/12/2021 22:38: First smoke detection in AFT UPS room activates.
2/12/2021 22:51 Full Muster.
2/12/2021 22:57: Operations initiated manual emergency shutdown (ESD) ESD1 to shutdown and depressured the process systems. EDG 10, and AFT + FWD Emergency Diesel Generators (EMDG) start automatically but did not sync to switchboard.
2/12/2021 23:16: Blackout: UPS 114V02 tripped resulting in Prelude losing all power causing loss of essential services such as: communication systems, potable water systems, sewerage treatment, and accommodation Heating Venting and Air Conditioning (HVAC).
3/12/2021 02:14: NOPSEMA was notified of incident and investigation initiated.
3/12/2021 midnight to 07.00 am: Facilities restored. Lighting restored, 2xEDGs running and synced, toilets restored, 1xaccommodation HVAC chiller started, communications restored.
3/12/2021 07:10: Decision by [REDACTED] to cancel scheduled Friday helicopter flights due to concern about fatigue of [REDACTED] and facility power stability.
3/12/2021 08:06 Muster Stood down. Note: Subsequent muster start and finish times post this time have not been included in this summary table. Refer to Appendix A for details of additional musters.
3/12/2021 14:12 to 19:14: Multiple EDG trips and restarts. Loss of essential services at 14:12.

Summary Date/Time and Event Description
3/12/2021 20:00 to 21.14: AFT EMDG Started, AFT EMDG Shutdown, AFT EMDG restarted. Lighting restored. Essential SOLAS switchboards online.
4/12/2021 12:15: EMDG Trip (Reverse Power Protection relay activated). No Public Address and General Alarm (PAGA). No radio Communications.
4/12/2021 14:20: Inbound helicopters turned around due to power failure – communicated via Infield Support Vessel (ISV).
4/12/2021 18:00: Removal of non-essential personnel using ISV begins. 58 total personnel (PAX) on 2 vessels.
5/12/2021 10:16 to 16:35: 7xhelicopters departed with 95 PAX total. Power supply restart and stabilisation throughout this period.
5/12/2021 14:28: All essential services restored.
9/12/2021: NOPSEMA inspectors arrive at Prelude FLNG to investigate incident.

Based on the information provided, the inspectors found that:

- The risk of major accident event (MAE) was reduced by the decision to shutdown and depressure the process system using ESD1 functionality early (within 30 minutes of smoke detection in the UPS room).
- The emergency response to the smoke detection in the UPS room was appropriate. However, several members of the emergency response team that made the controlled entry to the room under breathing apparatus did suffer from heat stress. The inspectors believe this may have resulted from wearing their turn-out firefighting suits in the hot substructure areas for extended periods before and after the room entry.
- Handheld radio communications during the emergency response were limited due to the failure of radio repeaters (including the Emergency Response Team (ERT) radio channel) within the substructure.
- [REDACTED] and other members of the workforce interviewed by the inspectors stated that the [REDACTED] update communications to the crew during the event were calm, informative and frequent.
- Throughout the unstable power period after the UPS fire the cumulative risk on the facility was significantly higher than normal. This was due to (but not limited to) disabled safety systems, disabled communication systems, elevated heat and humidity within the living quarters and all other spaces, fatigue (some personnel worked 30-plus hour shifts), slippery conditions due to condensation, difficulty of rescue (if required) from some locations in the substructure and cooling of the substructure in the vicinity of the liquid natural gas (LNG) storage tanks that could lead to catastrophic failure if unmitigated. The inspectors noted that:
  - The hot and humid conditions in the substructure workspaces, equipment rooms and living quarters were extreme while essential services such as HVAC were not available. Anecdotal evidence from personnel stated that temperatures reached 40-45°C in the living quarters with so much humidity that it was difficult to walk on the wet floors



- 7 people were treated for heat-related conditions during the event, including 4 who had to have intravenous solutions administered by the medics. Shell advised that all of these people were fully recovered.
- Throughout the incident the elevated risk was managed using tools such as management of change (MoC) processes, down manning (reducing POB from 293 to 150 at the time of the offshore inspection), risk assessment, manual temperature and pressure readings of cargo tanks in the field, and a buddy system for personnel undertaking recovery tasks.

At the time of the offshore inspection:

- The facility had restored Essential Diesel Generator power. The goal on the facility at the time of inspection was to maintain stable power supplies
- The inspectors sighted process safety risk controls that were implemented on the facility. An example of this was the re-instatement of glycol heating to cargo spaces to mitigate subcooling of the substructure adjacent to the LNG storage tanks
- Essential services had been restored including the living quarters habitability (HVAC, potable water, sewerage, galley operations) and communications
- Based on discussions with offshore personnel, including management, it was apparent to inspectors that normal personnel health and safety risk controls such as personal fatigue management processes had been reinstated. Note: The anonymous complaint received on 14 December that the *“operator was not acting on the results of fatigue assessments”* was further investigated and discussed with Shell onshore management on 20 December. The inspectors found that, based on the results of their discussions offshore, and Shell’s response to the inspectors’ further enquiries, this matter needs no further NOPSEMA action. In addition, only “essential personnel” were allowed at the facility, limited to 150 to ensure single cabin berthing (to minimise fatigue)
- A Forward Operating Base (FOB) had been established in Broome to debrief disembarked personnel, provide assistance from a [REDACTED], prepare incoming personnel for travel and conditions at the facility and to provide other assistance to personnel as required
- A [REDACTED] returned to the facility on 10 December ([REDACTED] had previously been available at the Broome FOB)
- Normal passenger and stores transfer to and from the facility by helicopter had been re-established
- There were still a number of risk gaps such as (but not limited to) potential air in the flare system and bypassed ESD and Fire and Gas safety system functionality. The offshore management informed the inspectors that these gaps were being managed using systems such as the MoC process.

To assess the history of this issue, the inspectors compared the power failure incidents of 2 December 2021 (this incident) and a power failure incident experienced at the Prelude facility in February 2020. It was found that while both incidents had failures of all power generation systems (including Steam Turbine Generators (STG), EDGs, EMDGs), unlike this incident there was no report to NOPSEMA of failures to critical systems (such as UPS, IPS and communication systems) during the February 2020 incident. As a result, the February 2020 incident was not considered further as part of this investigation.

The inspectors found that the Prelude FLNG facility, which requires control of the temperatures and pressures of hydrocarbon storage tanks, requires an immediate and sustained effort to restore power and critical safety functions if they are lost.

Based on the information provided, the inspectors found that the immediate risks to personnel resulting from the power outage on 2 December were being appropriately managed and the incident was under control at the time of the offshore investigation (9 – 10 December). However, the robustness of the facility power system is inadequately understood, including failure mechanisms, interdependency and recovery:

- Failure mechanisms: e.g. why power failed in the way that it did
- Interdependency: e.g. supply of fuel for the emergency generator
- Recovery: e.g. multiple repeated trips as generators brought on-line.

The impact of these issues directly resulted in extended timeframes to restore power. This directly impacted:

- Emergency response, safety critical equipment (such as communication and safety systems) and evacuation of non-essential personnel
- Habitability of the facility for the personnel on board (293 at the time of the event), including those involved in response/recovery operations
- Demands of process equipment required to effectively manage the LNG inventory e.g. flare management and temperature management of the substructure.

As a result, unless potential failures of critical systems including hotel services and safety critical equipment (such as communication and safety systems) are mitigated, the risk from this hazard will not be ALARP.

**Determine if there is an appropriate plan in place to: conduct a proper internal investigation, manage the immediate risks, return to compliance**

**Conduct a proper internal investigation and manage the immediate risks**

Due to the complexity of the Prelude FLNG power and control systems, the exact cause(s) of the initial UPS fire and subsequent failures, such as the EDG/EMDG trips and the IPS shutdown(s), were unknown at the time of the NOPSEMA investigation. At the time of the inspection Shell had initiated an internal investigation into this incident. The draft Terms of Reference (TOR) for the investigation provided to the inspectors stated that the:

- The purpose of the investigation is to:
  - Establish “*what caused the initial shutdown*” and “*what caused . . . power to the facility . . . to remain unstable for an extended period*”
  - “*Identify similarities between causes and/or line of sight between corrective actions from the 2020 investigation and causes identified in this 2021 incident*”
- The investigation team includes independent facilitators and electrical system experts as well as personnel from Prelude including [REDACTED].

Findings for management of the immediate risks, at the time of the offshore investigation, have been addressed in the previous section of this report. However, prior to re-establishment of stable power on the facility there was a period of heightened risk due to failure of safety critical services. The inspectors found that the investigation draft TOR do not seek to identify key lessons from the incident that the inspectors found to be critical in reducing risk should this type of incident occur again. Examples of these may include (but are not limited to):

- Unavailability of key information and systems, during the power outage, such as:
  - Key documentation including drawings on the facility during the power outage: Personnel had to rely on memory while conducting activities during the power outage
  - DCS and IPS systems: Critical process information such as pressure in storage tanks was unavailable through these systems (information was collected manually from the field)
  - Permit to work systems
- Emergency Response Team (ERT) personnel procedures: During inspector discussions with ERT members several key lessons were identified that could improve ERT outcomes in future (such as the heat exhaustion suffered by multiple ERT members during emergency response activities)
- Failure of critical communication devices:
  - At times the only method of communication to the shore was via radio relay from ISVs
  - Handheld radio communication between personnel on the facility was limited
- Potential improvements to systems:
  - That might mitigate the degradation of conditions in the living quarters and / or the ability to provide helicopter support. For example: Ensuring that “life-sustainment” systems are available during all foreseeable loss of power events – HVAC, potable water, sewerage, galley-power, refrigeration. The inspectors consider that another total power-outage, such as experienced in February 2020 and December 2021, is foreseeable and credible
  - That are required to recover from total power failure. For example: Diesel transfer pumps for SOLAS Emergency Marine Generators to run via EMDG switchboards, not Essential Diesel Generator switchboards
- Some black start procedures (such as DCS) were found to be inadequate and relied on vendor experts, who happened to be on board at the time of the incident, to restart
- Potential for a similar safety system shutdown to result in uncontrolled depressurisation of the facility which could exceed limits in the flare system
- Potential shortage of adequately trained personnel at the facility to engage in the troubleshooting and recovery activities over a sustained period

**The inspectors concluded that a Shell internal investigation is planned to determine the cause(s) of the power system issues that lead to this incident. However, the draft investigation scope provided did not plan to assess all of the issues associated with the incident to ensure the immediate risks (such as the multiple cases of heat exhaustion, failure of critical hotel services and safety critical systems (e.g.**

communications) or the potential to exceed the flare system design limits) during a future similar incident are identified and recommendations are made to mitigate them. The inspectors note that at the time of the investigation, planning for future investigations into the incident was in early stages. Subsequently, Shell has advised NOPSEMA that multiple reviews will be completed to ensure all associated risks are investigated and mitigated.

#### *Return to compliance*

Shell explained to the inspectors, throughout the investigation, that the facility systems and processes will only be determined to return to compliance (and normal operation) using systematic and methodical methods which include assurance activities defined by company processes and procedures, such as Statement of Fitness (SOF) requirements.

**At the time of writing this report the operator was planning to return to normal operation, after assurance activities are completed adequately. The inspectors conclude that until power to safety critical equipment is made reliable and robust, the operator should not proceed to restart the facility beyond essential operations.**

#### *Consideration if any offence has occurred or if there is immediate or significant threat requiring enforcement intervention by NOPSEMA*

**At the time of writing and based on the findings described in the report the inspectors concluded that:**

- **NOPSEMA should consider whether enforcement is justified to ensure the Prelude facility does not restart before power systems for safety critical equipment are assured in the event of future power generation instability**
- **The constrained timeline of this initial investigation did not allow the inspectors to consider whether any offence against the OPGGSA had occurred. This may be considered further in due course.**

## Abbreviations

ALARP	As Low as Reasonably Practicable
CCR	Central Control Room
DCS	Distributed Control System
EDG	Essential Diesel Generators
ERC	Emergency Response Centre
EMDG	Emergency Diesel Generators
ENMCS	Electrical Network Monitoring and Control System
ESD	Emergency Shutdown
ERT	Emergency Response Team
FAC	First Aid Case (first aid treatment only i.e. no IV fluids / medication)
FLNG	Floating Liquid Natural Gas
FOB	Forward Operating Base
HSR	Health and Safety Representative
HVAC	Heating Venting and Air Conditioning
IPS	Instrumented Protective System
ISV	Immediate Support Vessel
IV	Intravenous
LNG	Liquified Natural Gas
MoC	Management of Change
MTC	Medical Treatment Case (fluids / medication provided)
OIM	Offshore Installation Manager
OPGGs	Offshore Petroleum and Greenhouse Gas Storage Act 2006



PAGA	Public Address and General Alarm
PAX	People/persons/occupants
POB	Personnel on Board
RPE	Responsible Person Electrical
SOF	Statement of Fitness
SOLAS	Safety Of Life at Sea
STG	Steam Turbine Generators
TOR	Terms of Reference
UPS	Uninterruptible Power Supply

## Appendix A: DRAFT Timeline of events

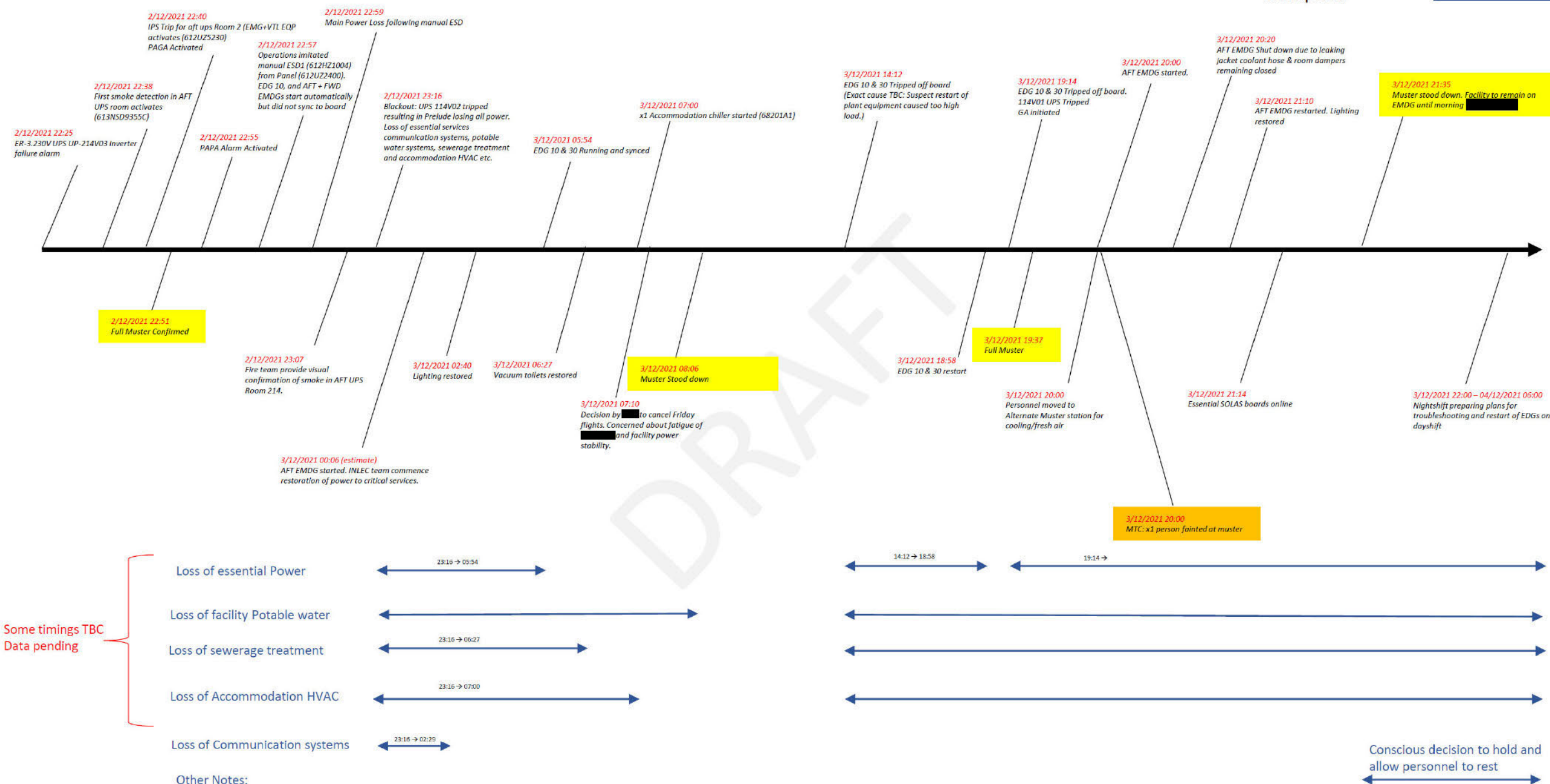
### DRAFT: 2<sup>nd</sup> Dec to 3<sup>rd</sup> December (not to scale)

Key:

Medical Treatment:

Muster:

Transport:



## DRAFT: 4<sup>th</sup> Dec to 5<sup>th</sup> December (not to scale)

Key:

Medical Treatment:

Muster:

Transport:

