MTS DP Committee

Workshop in Singapore 2018

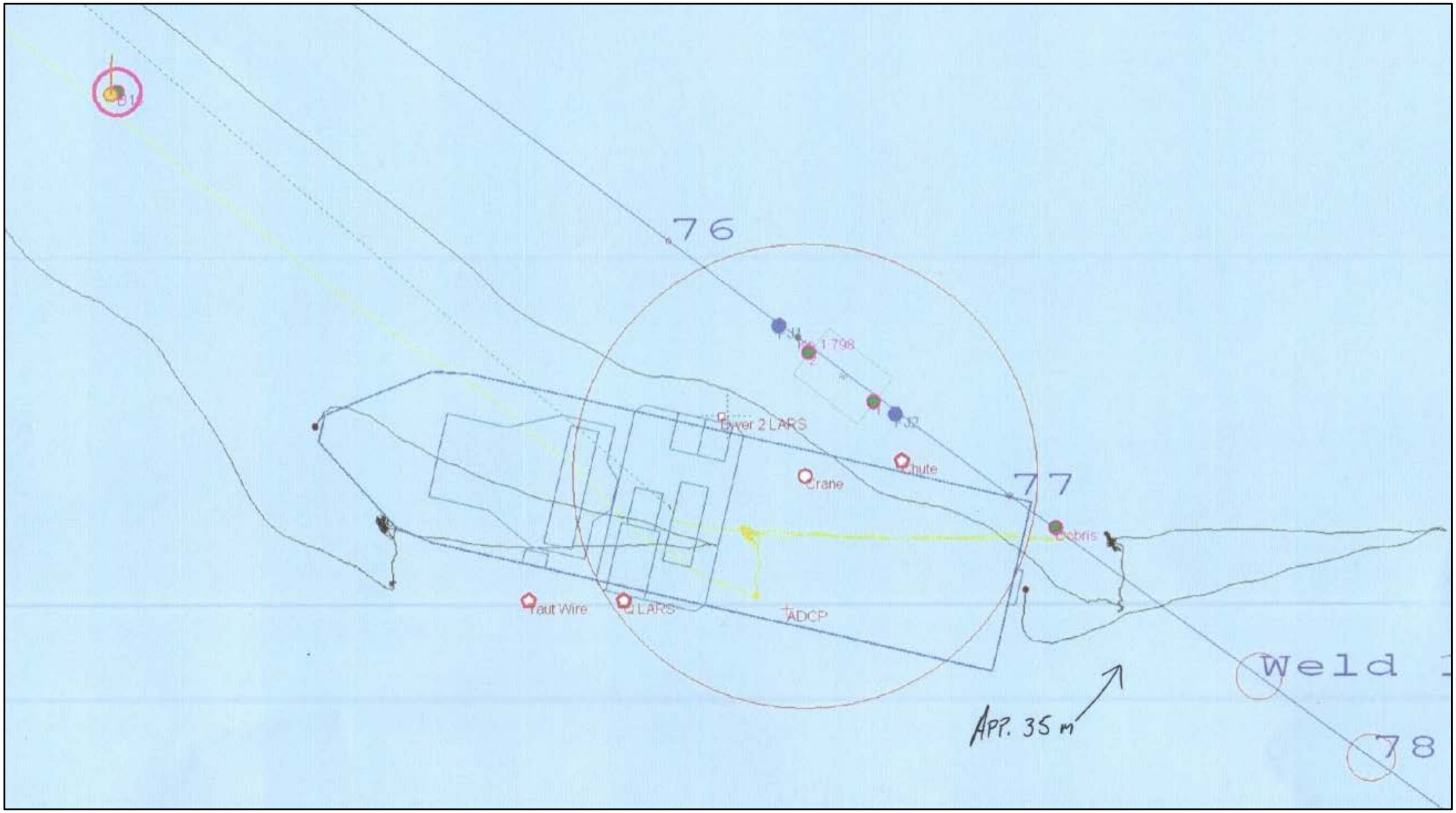
Session 4 – Day 2

Unwanted Thrust

Unwanted Thrust - Definition

- Unwanted Thrust
  - Thrust magnitude not what has been ordered by DP – (Particularly too high or full thrust)
  - Thrust direction not what has been ordered by DP

Drive Off on Diving Vessel



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Safety Alert

- High potential incident on diving vessel
- No consequences by chance only

GROUP DP ALERT-ACTION REQUIRED

UNWANTED THRUST- (EG FAILURE TO FULL PITCH)

DP Alert Number 01 / 17	P&T Projects Marine Risk Team	November 2017

RAPID LOSS OF POSITION / DRIVE-OFF DUE TO UNWANTED THRUST (FAILURE OF HYDRAULICS)

Target audience for this alert

- All Business Units operating DP Units
- Wells, Project, Logistics Communities using DP Vessels
- Authorized SMEs in Maritime Safety
- Diving Center of Excellence (DCOE)

WHY THIS ALERT IS BEING ISSUED

Recently, a loss of position incident was experienced on a DP dive support vessel. At the time of the incident, no divers were in the water. The vessel was being readied for operations. Circumstantial reasons were attributed to the lack of consequences for this loss of position.

This loss of position incident identified weaknesses in the procedural barriers in place to address the known vulnerability of thrusters failing to full pitch. The accepted barrier in place requires rapid operator intervention to emergency stop the thruster. (working the right side of the bow tie). The delayed response (74 seconds) resulted in a position excursion of ~70 metres. The demands on cognitive burden and immediate response validates the hierarchy of controls, highlighting the need for further effort to eliminate the hazard to address this vulnerability.

Preliminary conclusion derived from the ongoing investigative efforts has highlighted the following issues and actions to address them.

1. Additional emphasis on awareness of this issue (ASOG and Vessel Specific Procedure/Master's standing orders etc)
2. Positive verification of DP operator familiarization of procedures and response capability through documented drills and exercises.
3. Engagement with Industry to:
   - Highlight this issue
   - Seek ways to eliminate this hazard by design.

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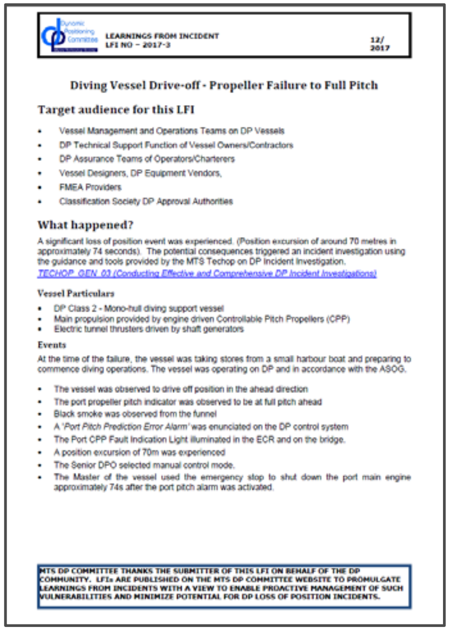
MTS LFI Drive-Off on Diving Vessel

- The vessel was observed to drive off position in the ahead direction
- The port propeller pitch indicator was observed to be at full pitch ahead Black smoke was observed from the funnel
- A ’*Port Pitch Prediction Error Alarm’* was enunciated on the DP control system
- The Port CPP Fault Indication Light illuminated in the ECR and on the bridge.
- A position excursion of 70m was experienced
- The Senior DPO selected manual control mode.
- The Master of the vessel used the emergency stop to shut down the port main engine approximately 74s after the port pitch alarm was activated.



LEARNINGS FROM INCIDENT
LFI NO – 2017-3

12/
2017

Diving Vessel Drive-off - Propeller Failure to Full Pitch

Target audience for this LFI

- Vessel Management and Operations Teams on DP Vessels
- DP Technical Support Function of Vessel Owners/Contractors
- DP Assurance Teams of Operators/Charterers
- Vessel Designers, DP Equipment Vendors,
- FMEA Providers
- Classification Society DP Approval Authorities

What happened?

A significant loss of position event was experienced. (Position excursion of around 70 metres in approximately 74 seconds). The potential consequences triggered an incident investigation using the guidance and tools provided by the MTS Techop on DP Incident Investigation.
TECHOP_GEN_03 (Conducting Effective and Comprehensive DP Incident Investigations)

Vessel Particulars

- DP Class 2 - Mono-hull diving support vessel
- Main propulsion provided by engine driven Controllable Pitch Propellers (CPP)
- Electric tunnel thrusters driven by shaft generators

Events

At the time of the failure, the vessel was taking stores from a small harbour boat and preparing to commence diving operations. The vessel was operating on DP and in accordance with the ASOG.

- The vessel was observed to drive off position in the ahead direction
- The port propeller pitch indicator was observed to be at full pitch ahead
- Black smoke was observed from the funnel
- A '*Port Pitch Prediction Error Alarm*' was enunciated on the DP control system
- The Port CPP Fault Indication Light illuminated in the ECR and on the bridge.
- A position excursion of 70m was experienced
- The Senior DPO selected manual control mode.
- The Master of the vessel used the emergency stop to shut down the port main engine approximately 74s after the port pitch alarm was activated.

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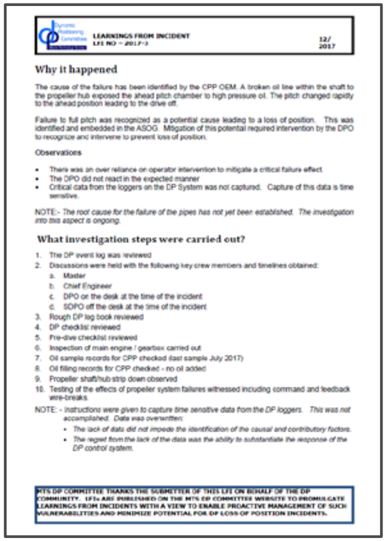
Why it happened

- The cause of the failure has been identified by the CPP OEM. A broken oil line within the shaft to the propeller hub exposed the ahead pitch chamber to high pressure oil. The pitch changed rapidly to the ahead position leading to the drive off.
- Failure to full pitch was recognized as a potential cause leading to a loss of position. This was identified and embedded in the ASOG. Mitigation of this potential required intervention by the DPO to recognize and intervene to prevent loss of position.



LEARNINGS FROM INCIDENT
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Why it happened

The cause of the failure has been identified by the CPP OEM. A broken oil line within the shaft to the propeller hub exposed the ahead pitch chamber to high pressure oil. The pitch changed rapidly to the ahead position leading to the drive off.

Failure to full pitch was recognized as a potential cause leading to a loss of position. This was identified and embedded in the ASOG. Mitigation of this potential required intervention by the DPO to recognize and intervene to prevent loss of position.

Observations

- There was an over reliance on operator intervention to mitigate a critical failure effect.
- The DPO did not react in the expected manner
- Critical data from the loggers on the DP System was not captured. Capture of this data is time sensitive.

NOTE:- *The root cause for the failure of the pipes has not yet been established. The investigation into this aspect is ongoing.*

What investigation steps were carried out?

1. The DP event log was reviewed
2. Discussions were held with the following key crew members and timelines obtained:
   a. Master
   b. Chief Engineer
   c. DPO on the desk at the time of the incident
   d. SDPO off the desk at the time of the incident
3. Rough DP log book reviewed
4. DP checklist reviewed
5. Pre-dive checklist reviewed
6. Inspection of main engine / gearbox carried out
7. Oil sample records for CPP checked (last sample July 2017)
8. Oil filling records for CPP checked - no oil added
9. Propeller shaft/hub strip down observed
10. Testing of the effects of propeller system failures witnessed including command and feedback wire-breaks.

NOTE: - *Instructions were given to capture time sensitive data from the DP loggers. This was not accomplished. Data was overwritten:*

- *The lack of data did not impede the identification of the causal and contributory factors.*
- *The regret from the lack of the data was the ability to substantiate the response of the DP control system.*

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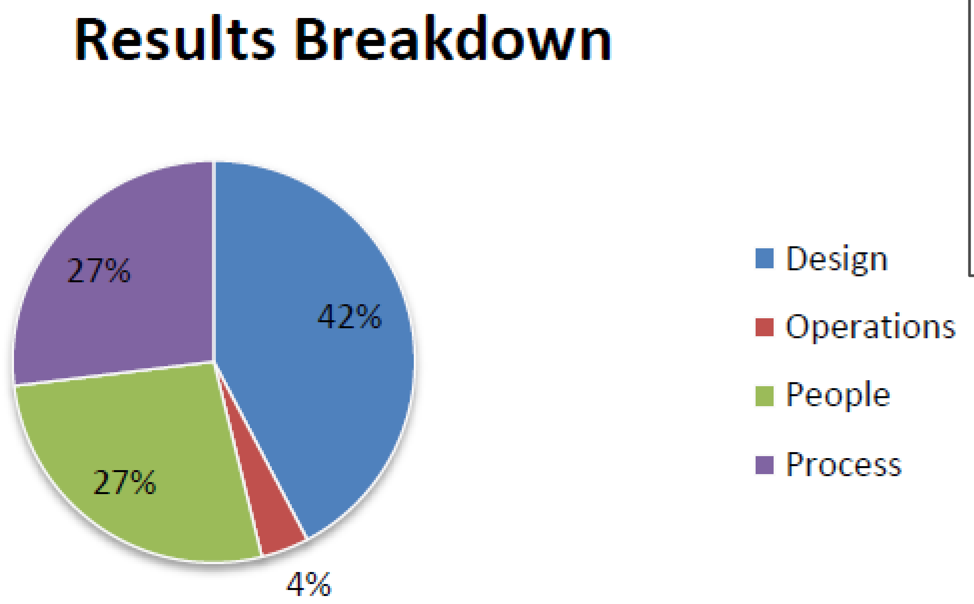
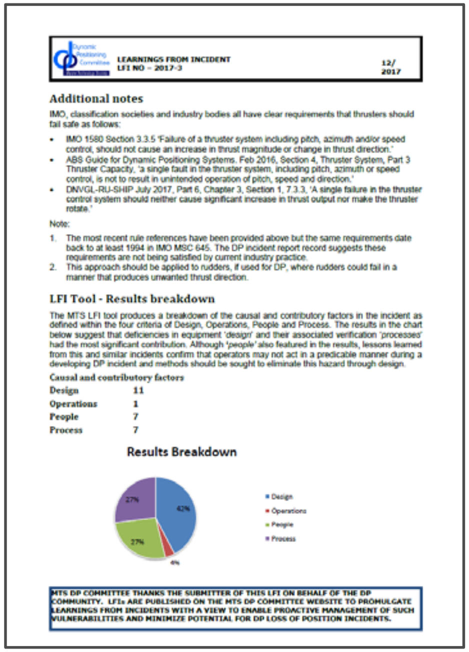
Lessons Learned

- Current industry practice to analyse and prove the fail-safe condition of thrusters falls short of achieving the objectives in established industry guidance and classification society rules.
- Verification and Validation Processes for the Fail-Safe Condition of Thrusters need to be more robust.
- The effectiveness of MOC processes must be validated
- Activities to undertake self-assurance must be in place. (Undue reliance should not be placed on Charterer’s 3rd party assurance) - (Example for assurance activities attached as appendix)
- Reliance on Operator Intervention and Human Performance is not a reliable method of limiting the severity of a drive off.
- Data capture following an incident is key. Procedures with sufficient level of detail must be developed and implemented. Training in execution should be provided to personnel key to the delivery of DP operations.

Results Breakdown from MTS LFI TOOL

Causal and contributory factors	
Design	**11**
Operations	**1**
People	**7**
Process	**7**





LEARNINGS FROM INCIDENT
LFI NO – 2017-3

12/ 2017

Additional notes

IMO, classification societies and industry bodies all have clear requirements that thrusters should fail safe as follows:

- IMO 1580 Section 3.3.5 'Failure of a thruster system including pitch, azimuth and/or speed control, should not cause an increase in thrust magnitude or change in thrust direction.'
- ABS Guide for Dynamic Positioning Systems. Feb 2016, Section 4, Thruster System, Part 3 Thruster Capacity, 'a single fault in the thruster system, including pitch, azimuth or speed control, is not to result in unintended operation of pitch, speed and direction.'
- DNVGL-RU-SHIP July 2017, Part 6, Chapter 3, Section 1, 7.3.3, 'A single failure in the thruster control system should neither cause significant increase in thrust output nor make the thruster rotate.'

Note:

1. The most recent rule references have been provided above but the same requirements date back to at least 1994 in IMO MSC 645. The DP incident report record suggests these requirements are not being satisfied by current industry practice.
2. This approach should be applied to rudders, if used for DP, where rudders could fail in a manner that produces unwanted thrust direction.

LFI Tool - Results breakdown

The MTS LFI tool produces a breakdown of the causal and contributory factors in the incident as defined within the four criteria of Design, Operations, People and Process. The results in the chart below suggest that deficiencies in equipment 'design' and their associated verification 'processes' had the most significant contribution. Although '*people*' also featured in the results, lessons learned from this and similar incidents confirm that operators may not act in a predicable manner during a developing DP incident and methods should be sought to eliminate this hazard through design.

Causal and contributory factors	
Design	**11**
Operations	**1**
People	**7**
Process	**7**

Results Breakdown

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Long Term Actions

- Engage with relevant stakeholder to seek ways to eliminate this hazard (unwanted thrust) by design.
- NOTE:- *There appears to be growing consensus that the fail-safe condition for thrusters while on DP should be to fail to Zero Thrust.*

LEARNINGS FROM INCIDENT
LFI NO – 2017-3

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Lessons learned

Current industry practice to analyse and prove the fail-safe condition of thrusters falls short of achieving the objectives in established industry guidance and classification society rules.

- Verification and Validation Processes for the Fail-Safe Condition of Thrusters needs to be more robust.
  - The effectiveness of MOC processes must be validated
  - Activities to undertake self-assurance must be in place. (Undue reliance should not be placed on Charterer's 3rd party assurance)- (Example for assurance activities attached as appendix)
- Reliance on Operator Intervention and Human Performance is not a reliable method of limiting the severity of a drive off.
- Data capture following an incident is key. Procedures with sufficient level of detail must be developed and implemented. Training in execution should be provided to personnel key to the delivery of DP operations.

Recommendations

Vessel owner(s) should evaluate their vessels to establish whether they are vulnerable to this type of failure. In particular, they should review the design of their thruster control systems and any associated protective functions to determine whether they address all possible failure modes leading to failure effects that produce significant quantities of unwanted thrust in both magnitude and direction.

Short term remedial actions

- Verify DP operator familiarity with procedures and response capability to identify and address unwanted thrust through documented drills and exercises.
- Seek ways to relieve the cognitive burden on the DPO.
- Place additional emphasis on awareness of this issue through ASOGs, vessel specific procedures and Master's standing orders etc.
- Developed verification and validation process for addressing configurable settings and performance of equipment. (Attached as appendix)

Medium term remedial actions

Engage with manufacturers, DP FMEA providers and classification societies to ascertain and establish that verification and validation processes are adequate to satisfy requirements to prove the fail-safe condition of thrusters.

Long term remedial actions

Engage with relevant stakeholder to seek ways to eliminate this hazard (unwanted thrust) by design.

NOTE:- *There appears to be growing consensus that the fail-safe condition for thrusters while on DP should be to fail to Zero Thrust.*

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Industry Rules and Guidelines

No need for new rules – only need to apply the ones we have:

- **IMO MSC 645** Section 3.3.4 ‘Failure of **thruster system** including pitch, azimuth or speed control, should not make the thruster rotate or go to uncontrolled full pitch and speed’.
- **IMO MSC 1580** Section 3.3.5 ‘Failure of a **thruster system** including pitch, azimuth and/or speed control, should not cause an **increase in thrust magnitude or change in thrust direction**.’
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Similar faults – Several instances of some type

- Azimuth feedback mechanical drive slips with respect to all potentiometers – destabilises DP control systems
- Thruster control systems adds ‘hidden’ 180 degrees to azimuth thrust direction
- Tunnel thuster changes direction on command signal failure
- Large main CPP fails to full pitch – command signal failure
- Tunnel thuster fails to full pitch – ground fault on solenoid valve
- Both main propellers drop out of DP and increase pitch

Long standing industry problem

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Design Issues

- Designs are not ‘fail-safe’
- Lack of clear separation between:
  - Control
  - Protection
  - Monitoring
- Some designs use same signal used for closed loop control, DP feedback and for indication at thuster control console – no independent display – no prediction error.
- Single and common mechanical drives for feedback
- Lack of an independent protective functions to monitor thuster performance and take action to prevent drive off

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Over reliance on operator intervention

- Unwarranted confidence in ability of operator to make correct choice under stressful conditions
- Misunderstandings – Operator expects thuster to be fail-safe – waits for non-existent protective function to act
- Lack of understanding about the effect of erroneous thrust magnitude or direction on DP system stability – Operator leaves thuster with prediction error selected to DP
- Lack of understanding regarding the significance of alarms
- May not understand that failed thruster will not respond to anything other than the emergency stop – no point selecting manual or IJS
- Some failure modes produce no prediction error – No decision support

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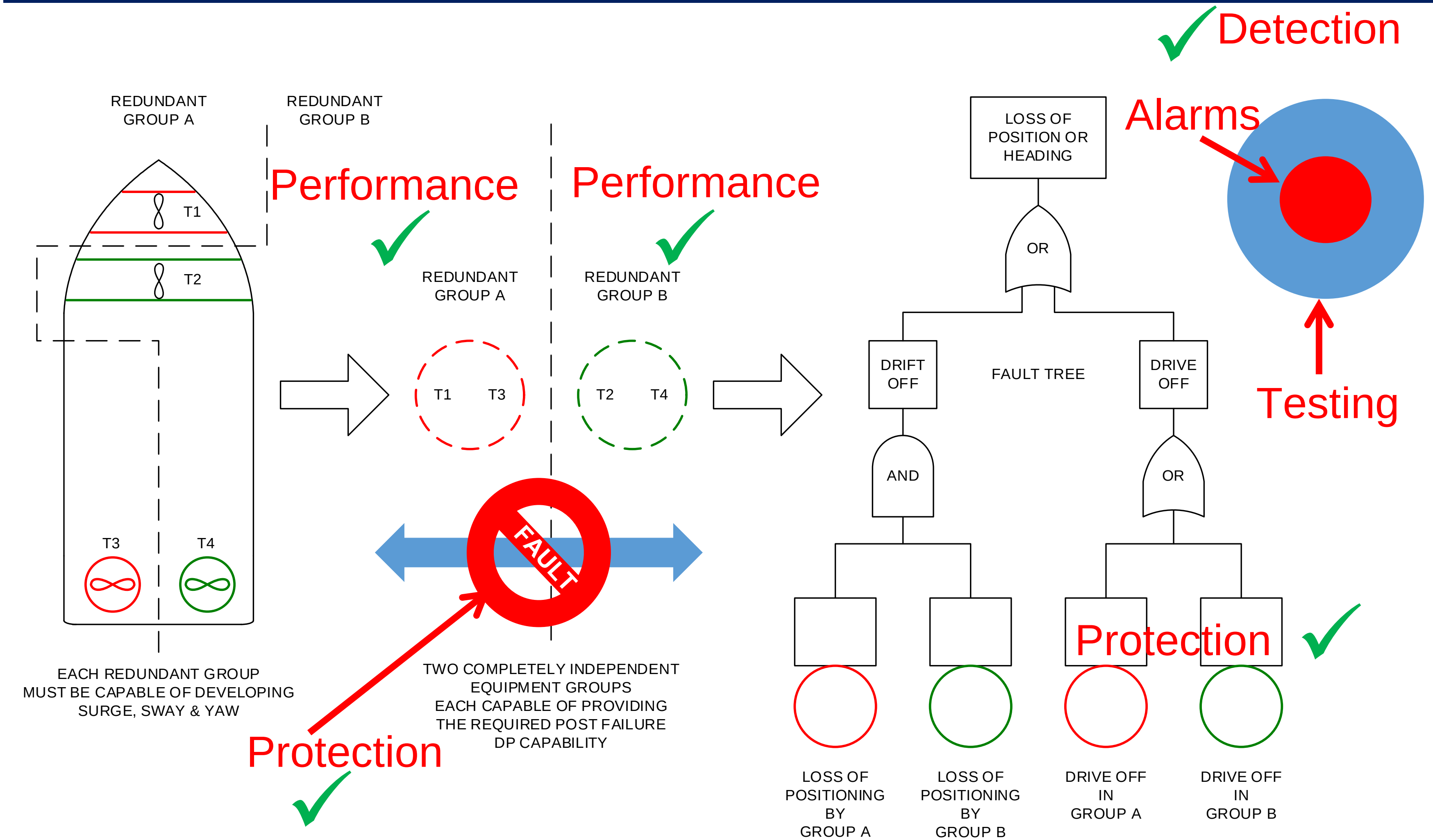
Protection Against Drive Off



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SIMPLE REDUNDANCY CONCEPT

Protective functions in DP systems

DP community is quite used to the role of protective functions in DP systems:

- Protection and fault propagation from system A to system B – Prevent Drift off e.g. protection that trips busties and shuts down fault generators
- Protection again erroneous DP Control Systems, Position Reference Systems and vessel sensors
- Where is the protection against the effects of faulty thrusters?

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Development of protective function against unwanted thrust

Development of an independent protective function against unwanted thrust:

- Independent:
  - One per thruster
  - Independent of the thruster control system and DP control systems
- Robust - Model based protection
- Provides condition monitoring and data logging
- Stops thruster when failure will lead to a drive off

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Focus Areas for DSVs

- Current industry practice to analyse and prove the fail-safe condition of thrusters falls short of achieving the objectives in established industry guidance and classification society rules.
- Verification and Validation Processes for the Fail-Safe Condition of Thrusters needs to be more robust.
  - The effectiveness of MOC processes must be validated
  - Activities to undertake self-assurance must be in place. (Undue reliance should not be placed on Charterer's 3rd party assurance)- (Example for assurance activities attached as appendix)
- Reliance on Operator Intervention and Human Performance is not a reliable method of limiting the severity of a drive off.

PROPULSION CONFIGURATION

Vessels with Single Stern Thruster being offered for Diving

- Such Vessels are vulnerable to loss of position.
- Dynamic Capability plots demonstrate the above (MTS DP Committee Paper)

- Vessels with DP notation equivalent to DP Equipment Class 2 or higher, both in the Intact condition and following worst case failure, shall be able to keep position and heading without relying on the combined use of propellers and rudders to develop transverse thrust.
- Vessels relying on combined use of rudders and propellers to develop transverse thrust following worst case failure shall not be used for diving operations.

CATEGORIES

CATEGORISATION DEPENDING ON PROPULSION CONFIGURATION

- **HIGHEST RISK TYPE I**
- **HIGH RISK TYPE II**

HIGHEST RISK

DP vessels with configurations where unwanted thrust due to failure of thruster(s) to full thrust by any means, requires immediate DP operator intervention to prevent unacceptable consequences of a loss of position.

As examples:

DP DSV with tunnel thrusters providing thrust in sway / yaw and CPPs providing thrust in surge.

DP Vessels where unwanted thrust in surge axis can rapidly cause loss of position

- DP DSV with two CPP’s as main props for thrust in surge axis.
- DP Shuttle tanker.
- MODUs and Construction vessels with two CPPS as main props for thrust in surge axis.

DP DSVs IDENTIFIED AS HIGHEST RISK WILL BE CLASSED AS TYPE 1 DP DSV

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HIGH RISK

HIGH RISK

DP vessels with configurations where unwanted thrust due to failure of a thruster to full thrust by any means can be counteracted by other thrusters and may not solely rely on DP operator intervention to prevent unacceptable consequences of a loss of position

As examples:

- DP Vessels with fixed pitch azimuth thrusters
- DP vessels with a combination of tunnel and azimuthing thrusters capable of counteracting unwanted thrust caused by failure of a single thruster.

DP DSV's IDENTIFIED AS HIGH RISK WILL BE CLASSED AS TYPE 2 DP DSV

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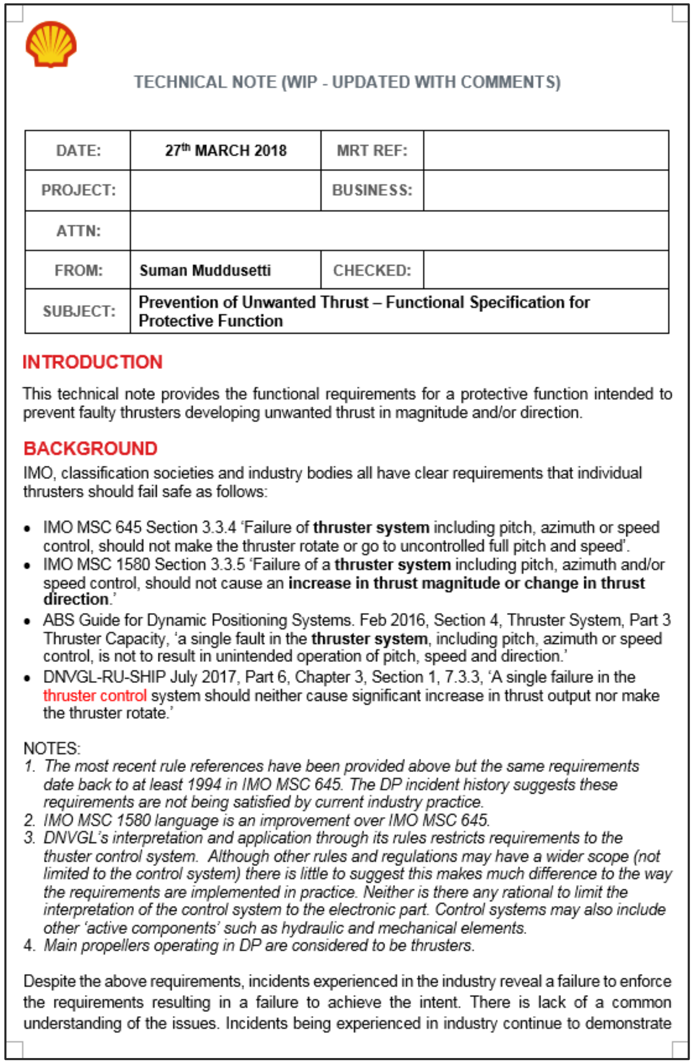
Functional Spec for Independent Protective Function

- Draft Functional Spec for an independent protective function to counter the risk of unwanted thrust



TECHNICAL NOTE (WIP - UPDATED WITH COMMENTS)

DATE:	27th MARCH 2018	MRT REF:	
PROJECT:		BUSINESS:	
ATTN:			
FROM:	Suman Muddusetti	CHECKED:	
SUBJECT:	Prevention of Unwanted Thrust – Functional Specification for Protective Function		

INTRODUCTION

This technical note provides the functional requirements for a protective function intended to prevent faulty thrusters developing unwanted thrust in magnitude and/or direction.

BACKGROUND

IMO, classification societies and industry bodies all have clear requirements that individual thrusters should fail safe as follows:

- IMO MSC 645 Section 3.3.4 'Failure of **thruster system** including pitch, azimuth or speed control, should not make the thruster rotate or go to uncontrolled full pitch and speed'.
- IMO MSC 1580 Section 3.3.5 'Failure of a **thruster system** including pitch, azimuth and/or speed control, should not cause an **increase in thrust magnitude or change in thrust direction**.'
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NOTES:

1. *The most recent rule references have been provided above but the same requirements date back to at least 1994 in IMO MSC 645. The DP incident history suggests these requirements are not being satisfied by current industry practice.*
2. *IMO MSC 1580 language is an improvement over IMO MSC 645.*
3. *DNVGL's interpretation and application through its rules restricts requirements to the thuster control system. Although other rules and regulations may have a wider scope (not limited to the control system) there is little to suggest this makes much difference to the way the requirements are implemented in practice. Neither is there any rational to limit the interpretation of the control system to the electronic part. Control systems may also include other 'active components' such as hydraulic and mechanical elements.*
4. *Main propellers operating in DP are considered to be thrusters.*

Despite the above requirements, incidents experienced in the industry reveal a failure to enforce the requirements resulting in a failure to achieve the intent. There is lack of a common understanding of the issues. Incidents being experienced in industry continue to demonstrate

Recommendations

- Vessel owner(s) should evaluate their vessels to establish whether they are vulnerable to this type of failure.
- They should review the design of their thruster control systems and any associated protective functions to determine whether they address all possible failure modes leading to failure effects that produce significant quantities of unwanted thrust in both magnitude and direction.
- Engage with relevant stakeholder to seek ways to eliminate this hazard (unwanted thrust) by design.
- NOTE:- *There appears to be growing consensus that the fail-safe condition for thrusters while on DP should be to fail to Zero Thrust.*

Workshop Exercise

- Do we believe we understand this issue well enough?
- Do we have effective verification and validation to address this issue?
- Your thoughts on what we are doing today? (verification & validation)
- How would you influence the way this issue is addressed?

Thank You