UNWANTED THRUST !

"HAVE WE DONE ENOUGH?"

Suman Muddusetti

PRINCIPAL MARINE OPERATIONS ENGINEER - MARINE RISK TEAM LEAD

SHELL INTERNATIONAL EXPLORATION AND PRODUCTION (Projects and Technology)

Outline

- Leveraging MTS LFI on Unwanted Thrust
  - Introspection and Reflection
  - Dilemmas
  - Developing Clarity
- A Systems Approach to implementation of the LFI
- Actions
  - Internal
  - External
- Predictable Outcomes - Can We do More?

Leveraging MTS - LFI

- Verify DP Operator familiarity with procedures and response
- Seek ways to relieve the cognitive burden
- Place additional emphasis on awareness through ASOG
- Develop verification and validation process for configurable settings
- Engage with manufacturers and classification societies to satisfy requirements
- Engage with relevant stakeholders to eliminate hazard by design

Dynamic Positioning Committee

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 [illegible]
- 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.

MTS DP COMMITTEE THANKS THE SUBMITTER OF THIS LFI ON BEHALF OF THE DP COMMUNITY. LFIs ARE PUBLISHED ON THE MTS DP COMMITTEE WEBSITE TO PROMULGATE LEARNINGS FROM INCIDENTS WITH A VIEW TO ENABLE PROACTIVE MANAGEMENT OF SUCH VULNERABILITIES AND MINIMIZE POTENTIAL FOR DP LOSS OF POSITION INCIDENTS.

Dynamic Positioning Committee

LEARNINGS FROM INCIDENT
LFI NO – 2017-3
12/ 2017

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 the 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.*

Introspection and Reflection

A LOOK BACK!

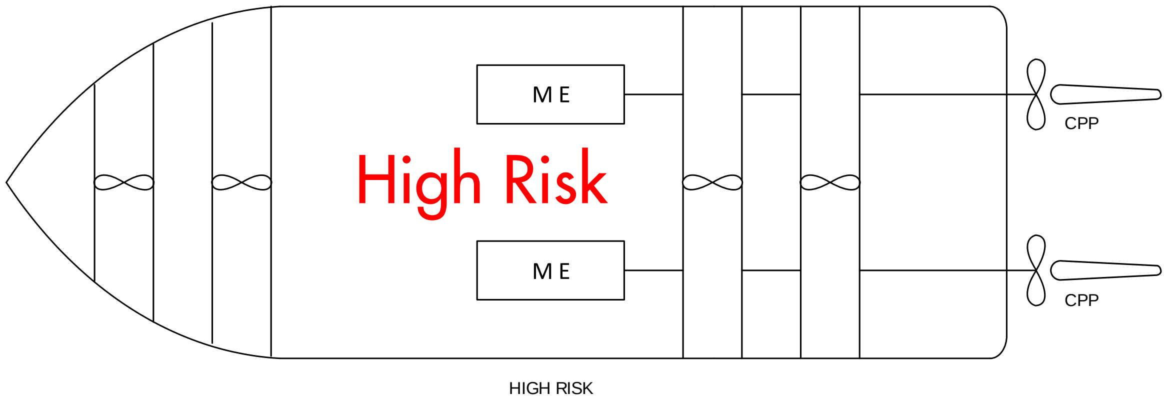
- Similar Incidents had been experienced, albeit on Logistic Vessels
  - No Consequences- Incidents had occurred outside the 500 m zone
  - Operator intervention was accepted as a credible mitigation
  - Incorporated in ASOG's

OPPORTUNITIES

- A Gift
  - Implement Learnings adopting a Systems Thinking Approach
  - Address through lens of Design Operations People and Process
  - Process Improvements
    - Stakeholder engagement
    - Classification of Incidents

Identification - (Classification of Vessels – TYPE 1 or TYPE 2)

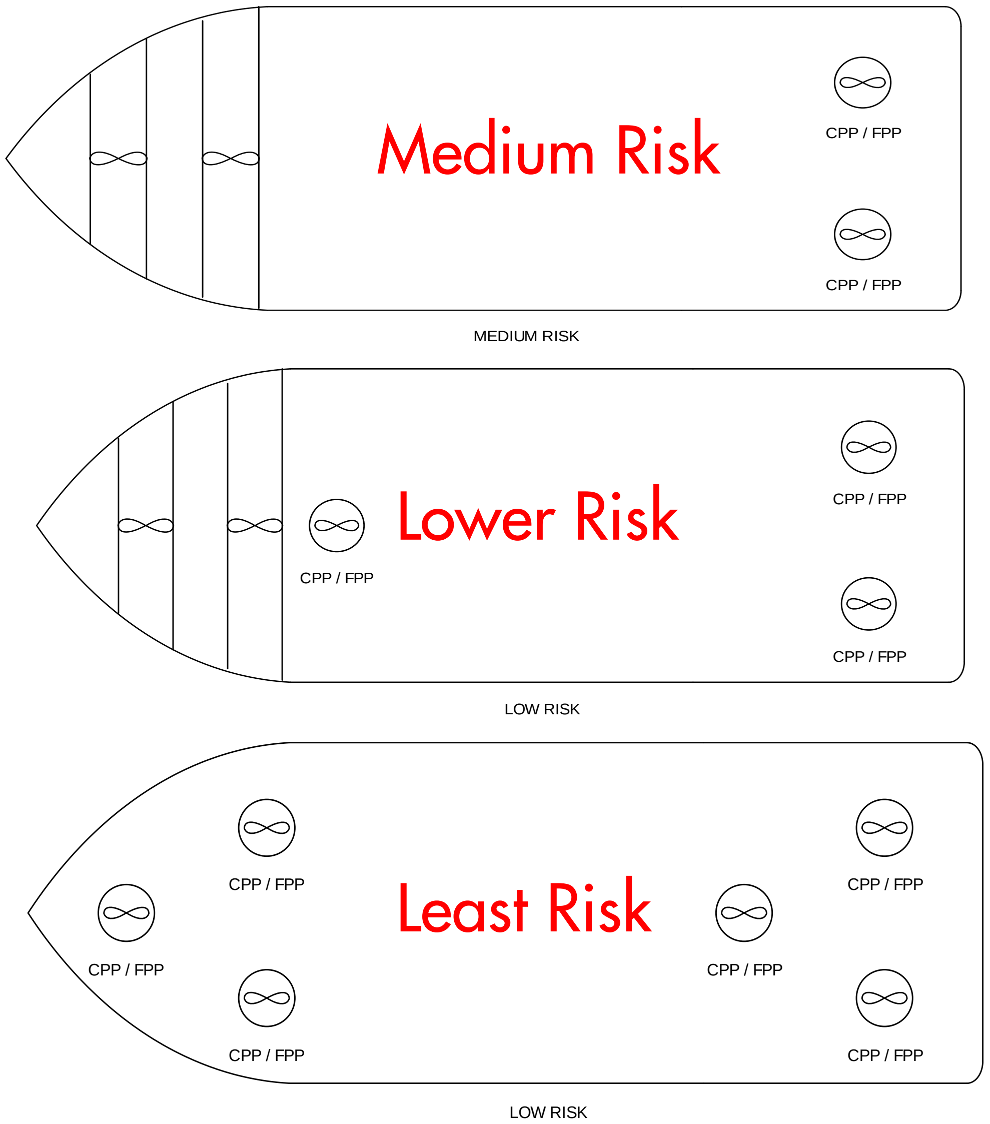
TYPE 1 VESSEL



TYPE 1 VESSEL

- MECHANICALLY DRIVEN CPP"S (USUALLY SHAFT GENERATORS PART OF CONFIGURATION)
- SWAY BY TUNNEL THRUSTERS
- SURGE AXIS ONLY BY MAIN PROPS
  - PROPS EFFICIENCY IN AHEAD DIRECTION
  - CPP"S FAILURE MODES
  - USUALLY HIGHER THRUST CAPABILITY
  - LIMITED COUNTERACTING CAPABILITY FOR UNWANTED THRUST IN SURGE AXIS
- HIGH RELIANCE ON OPERATOR INTERVENTION TO ADDRESS UNWANTED THRUST

Identification - (Classification of Vessels TYPE 2)

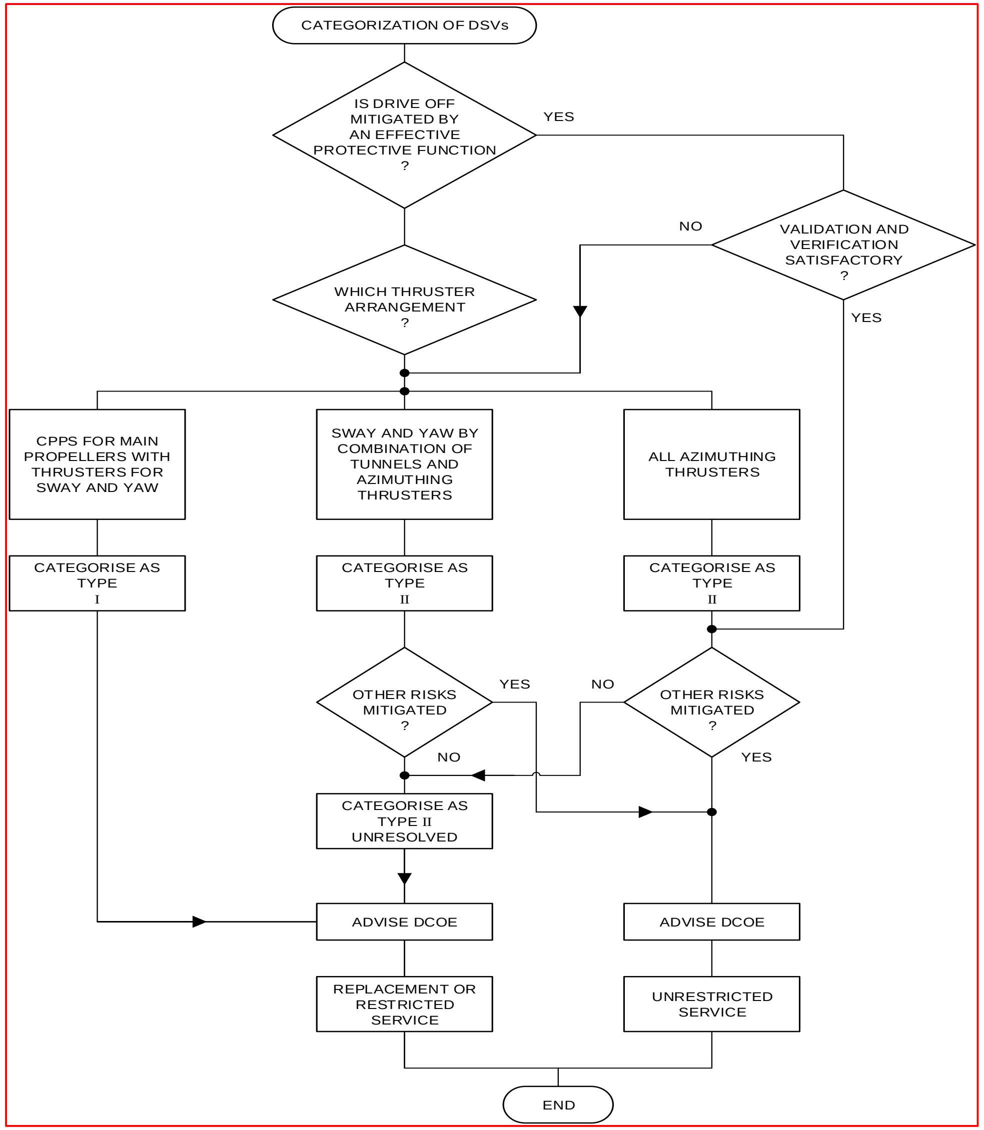


TYPE 2 VESSEL

- AZIMUTHING THRUSTER
  - Could be CPP's or FPP's
  - FPP's not immune to unwanted thrust- Directionality Failures of Azimuthing Mechanism.
- LOW RISK AND MEDIUM RISK VESSELS
  - Differentiator – Counteracting Ability
  - Number of Propulsors available for counter acting
- **UNRESOLVED IDENTIFIED VULNERABILITY LEADS TO RECLASSIFICATION OF TYPE 2 TO TYPE 1!**

Early Identification and Notification Enables Planning!

Categorisation



Notification

TECHNICAL NOTE

DATE:	07 FEB 2018	MRT REF:	MRT_DPDSV_DCOE NOTIFICATION-(DATE)
PROJECT:	GENERAL	BUSINESS:	GROUP
ATTN:	PTE DIVING/BUSINESS FOCAL POINT (INSERT NAMES)		
FROM:	**Suman Muddusetti**	CHECKED:	N/A
SUBJECT:	DP DSV (INSERT NAME) - IDENTIFICATION AS DP DSV TYPE 1 AND OR TYPE 2 VESSEL WITH POTENTIAL VULNERABILITIES THAT NEED RESOLUTION		

BACKGROUND

Learning from a significant High Potential near miss with a DP DSV has been incorporated into assurance process currently being undertaken by the Marine Risk team. One of the actions arising out of the follow through with the investigation was the commitment to notify DCOE and the Business Focal Point of identification of a vessel as a Type 1 DP DSV.

TYPE 1 DP DSVs are those that have a potential vulnerability for a rapid loss of position due to specific configurations of the propulsion system. TYPE 1 DSVs rely on operator intervention as a barrier to prevent the consequences of certain failure modes. Learning from incidents have concluded that such reliance on operator intervention alone is not a dependable barrier. Additional focus will be required on the management of station keeping risks as well as planning for the conduct of the diving operations.

While not common, in some cases DP DSVs identified as TYPE 2 may also need additional focus to resolve identified vulnerabilities.

Notification will be made to the DCOE and business focal point immediately If a vessel has been identified as a TYPE 1 vessel or a TYPE 2 vessel with vulnerabilities that need resolution.

It is understood that if a TYPE 1 vessel and or a TYPE 2 Vessel that has not been able to satisfactorily resolve identified vulnerabilities cannot be substituted with a suitable alternate vessel, will result in significant impacts to the business/project. Examples of some such impacts are:

- Additional tasks associated with the assurance activities
- Potential for precluding the conduct of certain diving activities (e.g. confined space diving) and/or development of additional mitigations/responses to a loss of position.
- Potential for cost increases (assurance tasks, non-productive time etc.)

STATEMENT

Please be advised that the DP DSV has been identified as a (TYPE1/TYPE 2 With need for Resolution)

Notification is being made as part of the agreed protocols.

TYPE 2 (WITH NEED FOR RESOLUTION)

The following are the vulnerabilities identified on this TYPE 2 Vessel.

S. No	Issue	Potential Impacts	Remarks

The undersigned or designate is available for further discussions as needed. Please keep us advised of the path forward that you would like us to pursue. Your prompt action on providing the steer to the Marine Risk Team is greatly appreciated.

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Implementing The LFI - Verification Activities of the Fail Safe Condition Of Thrusters

LFI Addendum

Addendum to LFI 2017-3

EXAMPLE VERIFICATION ACTIVITIES FOR FAIL SAFE CONDITION OF THRUSTERS

PURPOSE OF ADDENDUM: -

This document outlines an example verification process to address self-assurance activities for fail safe condition of thrusters. This may be used to document and make available the outcome of verification activities.

BACKGROUND: -

THRUSTER FAIL-SAFE REQUIREMENTS:

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:

- *The most recent rule references have been provided above but the same requirements date back to at least 1994 in IMO MSC 645.*
- *The requirements to prevent unwanted thrust direction also apply to rudders.*

VERIFICATION

The following Information pertinent to the fail-safe condition of thrusters is documented.

- Documented evidence of verification activities in a suggested format.
- Statement of Verification.

DOCUMENTED EVIDENCE OF VERIFICATION ACTIVITIES

Complete tables below:

For Each Azimuthing Thruster				
	Ahead	Port	Starboard	Astern
Confirm mechanical zero and electrical zero align – Then confirm azimuth angle at DP and all other indicators.				
Confirm angle by observation of thruster wash				
	Pump 1	Pump 2	Pump 1 & 2	
Record turning speed CW for Time for 360°				
Record turning speed CCW Time for 360°				

For Each Fixed Pitch Propeller				
	Motor current (A)	Motor current (%)	Motor Speed (RPM)	Motor Speed (%)
Set manual Levers to 100% Forward – Record Motor current and RPM				
Set manual Levers to 100% Reverse (where available) – Record Motor Current and RPM				
Using manual levers record ramp time from 0 to 100%				
Note ramp time for ramp 100% to 0				
Confirm thrust direction by observation of thruster wash				

Thrust Allocation - Excursion on Change of Allocation Mode	
For vessels with the potential to use different thrust allocation modes such as Bias and Free, orient the vessel beam on to the prevailing conditions and provoke a change of thrust allocation mode. Record the maximum position and heading excursion.	
For Vessels with Variable Speed / CPPs ('Combinator Mode'), clear statement to be provided whether DP operations are to be carried out with fixed speed or variable speed. DP documentation to be provided substantiating stable DP capability (footprint plots, statement from OEM that vessel is tuned and stable station keeping ability has been validated etc.) if variable speed is permitted for DP station keeping.	

Azimuth Thruster & Fixed Pitch Propellers

- Confirmation of Mech and Elec Zero
- Confirm azimuth feedback at 0° 90 ° 180 ° and 270°
- Confirmation of angle by thruster wash
- Turning rate CW and CCW

- RPM at 100% Forward and Reverse
- Ramp time 0 - 100% RPM
- Confirmation of direction by thruster wash

Thrust allocation

- Excursion between mode changes
- Confirmation of use of combinator mode

Implementing The LFI - Verification Activities of The Fail Safe Condition of Thrusters

Main Engine Driven Props - CPPs

For Main Engine Driven CPPs – Including Combinators						
Item	**Description**	**Port ME Ahead**	**Stbd ME Ahead**	**Port ME Astern**	**Stbd ME Astern**	**Remarks**
Load and speed settings (ahead and astern)	Load settings on the engine will be tested, verified and documented.	(kW, RPM)	(kW, RPM)	(kW, RPM)	(kW, RPM)	
Pitch stroke setting	Pitch stroke setting to be measured and documented	(%)	(%)	(%)	(%)	
Full Ahead / Full Astern (Pitch Stroke vs ME Load)	ME loads at **Full Ahead** and **Full Astern** to be documented	(%, kW, RPM)	(%, kW, RPM)	(%, kW, RPM)	(%, kW, RPM)	
Mid-range ahead and astern (pitch stroke vs ME loads	ME loads at **mid-pitch** stroke to be documented	(%, kW, RPM)	(%, kW, RPM)	(%, kW, RPM)	(%, kW, RPM)	
Zero pitch stroke vs ME loads	ME load at **Zero pitch** stroke to be documented	(%, kW, RPM)		(%, kW, RPM)		
Vibration	Subjective test to document vibrations when main props are full ahead and full astern	(Vibration)	(Vibration)	(Vibration)	(Vibration)	
Verify configurable settings in ECR on main prop for alignment with ASOG	Verify settings are as demonstrated and documented at tests.	(%, kW, RPM)	(%, kW, RPM)	(%, kW, RPM)	(%, kW, RPM)	

Motor Driven Props - CPPs

For Electrically Driven CPPs – Including Combinators						
Item	**Description**	**Port CPP Ahead**	**Stbd CPP Ahead**	**Port CPP Astern**	**Port CPP Astern**	**Remarks**
Load settings	Settings to be verified and documented	(kW, A, RPM)	(kW, A, RPM)	(kW, A, RPM)	(kW, A, RPM)	
Pitch stroke setting	Settings to be verified and documented	(%)	(%)	(%)	(%)	
Full Ahead / Full Astern (Pitch Stroke vs motor Load & Speed)	Motor load, current, speed and pitch stroke at **full ahead** and **full astern**	(%, kW, A, RPM)	(%, kW, A, RPM)	(%, kW, A, RPM)	(%, kW, A, RPM)	
Mid-range ahead and astern (pitch stroke vs motor load and Speed	Motor load, current, speed and pitch stroke at **Mid Stroke**	(%, kW, A, RPM)	(%, kW, A, RPM)	(%, kW, A, RPM)	(%, kW, A, RPM)	
Zero pitch stroke vs motor load & Speed	Motor load, current, speed and pitch stroke at **Zero Pitch**	(%, kW, A, RPM)		(%, kW, A, RPM)		
Vibration	Document vibrations when props are full ahead and full astern	(Vibration)	(Vibration)	(Vibration)	(Vibration)	
Verify configurable settings on props for alignment with ASOG	Verify settings are as demonstrated at tests.	(%, kW, A, RPM)	(%, kW, A, RPM)	(%, kW, A, RPM)	(%, kW, A, RPM)	

Main Engine and Electrically Driven CPP's

- Load and speed settings ahead and astern
- Pitch stroke settings
- Pitch stroke V ME load (Full - ahead and astern)
- Pitch stroke V ME load (Mid - ahead and astern)
- Zero pitch stroke V ME Load
- Vibration
- Verify configurable settings for main props for alignment with ASOG

- Load setting
- Pitch stroke settings
- Pitch stroke V motor load and speed (Full - ahead and astern)
- Pitch stroke V motor load and speed (Mid - ahead and astern)
- Zero pitch stroke V motor load and speed
- Vibration
- Verify configurable settings for main props for alignment with ASOG

EFFECTIVE STAKEHOLDER ENGAGEMENT

INTERNAL

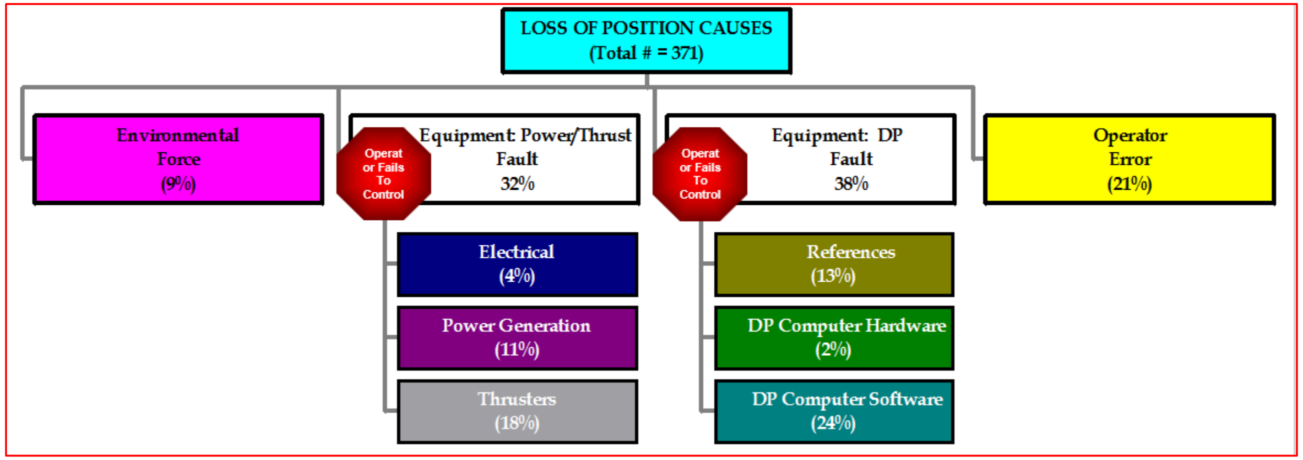
- OPERATNG COMPANIES/DIVING CENTER OF EXCELLENCE (DCOE)/PROJECTS
  - ACTIVITIES/PROJECTS IN EXECUTION
  - DISSEMINATION OF LFI
  - CENTRALIZED ACCOUNTABILITY AND ENABLER!
- BUSINESS IMPACTS
  - MANAGED EFFECTIVELY
    - WORK SCOPE ADJUSTMENTS
    - FOCUSED VALIDATION/VERIFICATION BASED ON RISK IDENTIFICATION

EXTERNAL ENGAGEMENT

- PARTNERS IN SAFETY (CONTRACTOR/VESSEL TECHNICAL OPERATORS AND 3P CONSULTANTS)
- DP COMMUNITY (OEM VENDORS/CLASSIFICATION SOCIETY)
- VERIFICATION AND VALIDATION EFFORTS
- ADDRESSING LONGER TERM MEASURES_ “DESIGN IT OUT”
- MTS DP COMMITTEE WORKSHOPS

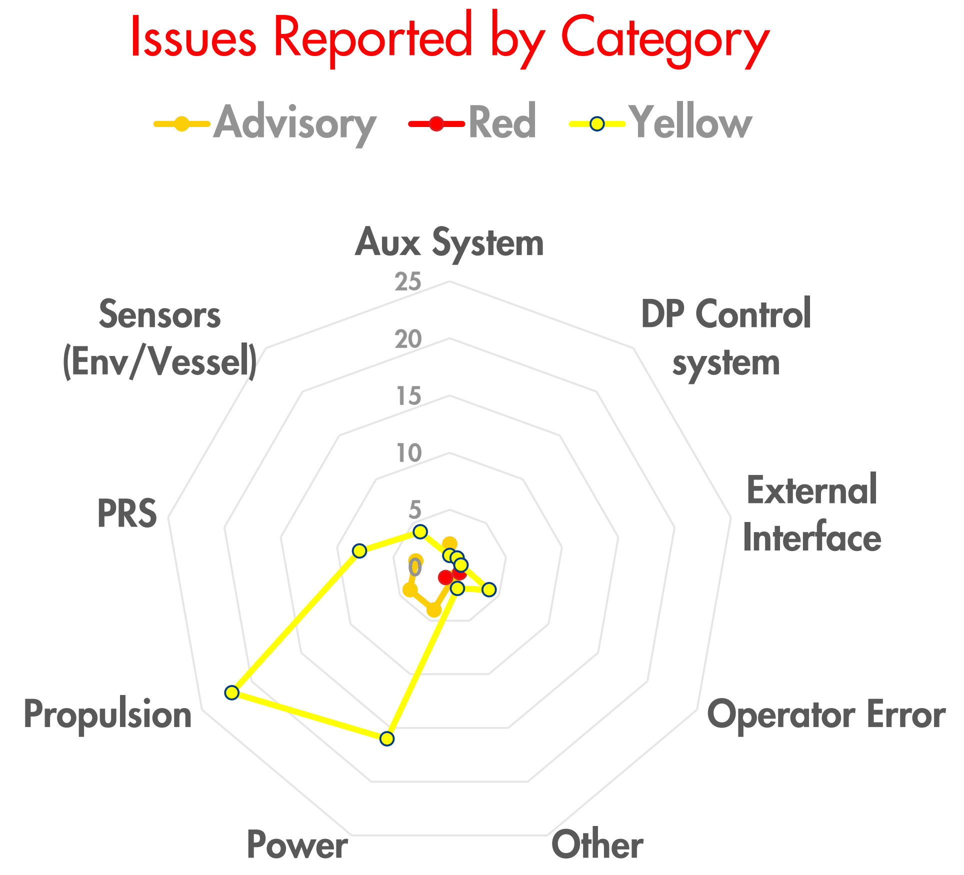
Overview of Causal and Contributory Factors of Loss of Position Then and Now!

DISTRIBUTION 9 : 32 : 38 : 21

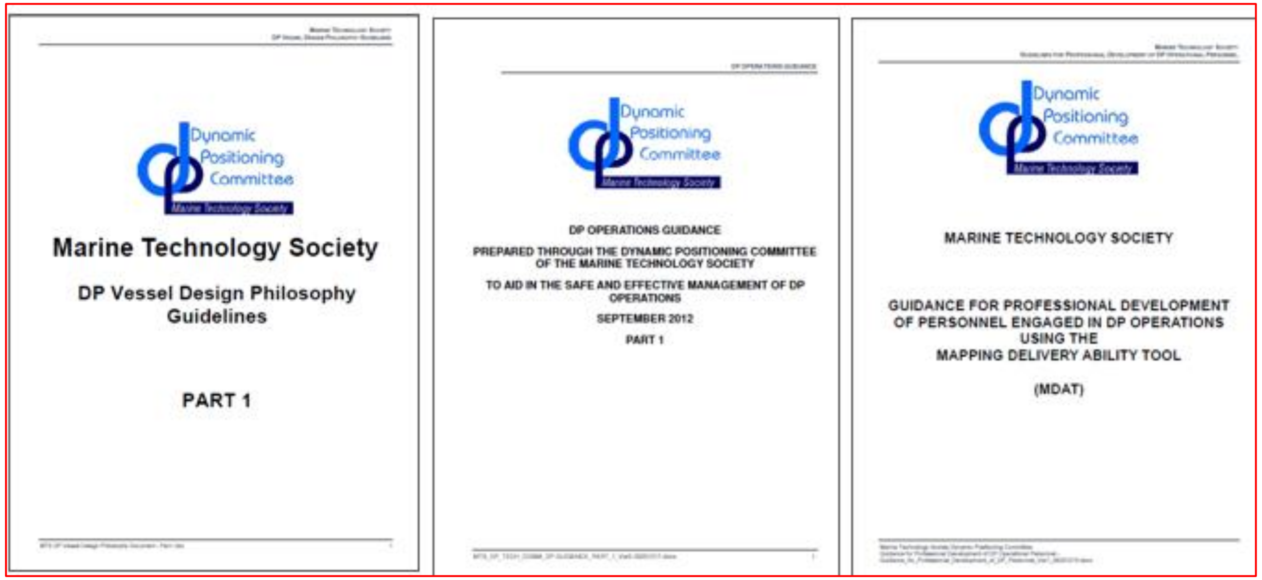


Environment 9%
Power Thrust 32%
DP Control 38%
Operator 21%

Information From Yellow And Red Tracker



Leveraging MTS Products!



Dynamic Positioning Committee
Marine Technology Society

Marine Technology Society

DP Vessel Design Philosophy Guidelines

PART 1

Dynamic Positioning Committee
Marine Technology Society

DP OPERATIONS GUIDANCE

PREPARED THROUGH THE DYNAMIC POSITIONING COMMITTEE OF THE MARINE TECHNOLOGY SOCIETY

TO AID IN THE SAFE AND EFFECTIVE MANAGEMENT OF DP OPERATIONS

SEPTEMBER 2012

PART 1

Dynamic Positioning Committee
Marine Technology Society

MARINE TECHNOLOGY SOCIETY

GUIDANCE FOR PROFESSIONAL DEVELOPMENT OF PERSONNEL ENGAGED IN DP OPERATIONS USING THE MAPPING DELIVERY ABILITY TOOL

(MDAT)

Dynamic Positioning Committee
Marine Technology Society

Independent Performance Validation for Robust and Resilient DP Systems

Steven Cargill* Chunying Li**

DNV GL Noble Denton marine services
***** Aspin Kemp & Associates***

marine technology SOCIETY
Opportunity runs deep™

- Design philosophy guidelines
- Operations guidance
- PDDP2 (formerly MDAT)
- IPV

Leveraging MTS DP Committee Products!

PERFORMANCE

DIGITILIZATION

PROTECTION

INDUSTRIAL MISSION

PREDICTABILITY

DATA CENTRICITY

DETECTION

Dynamic Positioning Committee
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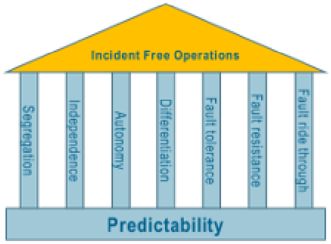


MTS GUIDANCE DOCUMENTS

TECHOPS

MODEL BASED TECHNIQUES

REDUCING COGNITIVE BURDEN

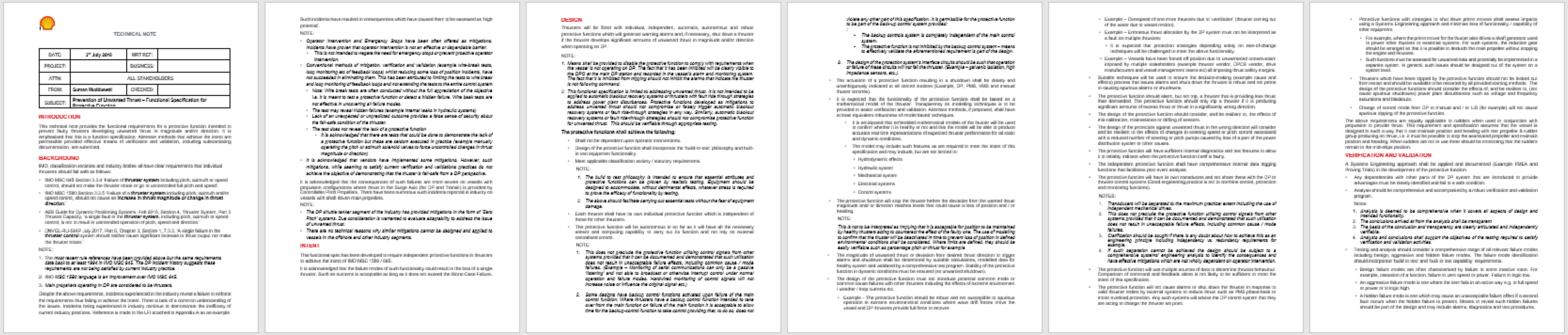
TECHNOLOGY AND INNOVATION

INDEPENDENT PERFORMANCE VALIDATION

OUTCOME FOCUS

Addressing Unwanted Thrust - (IPV) - Functional Specification

Specification for Independent Protective function



- Introduction
- Background
- Intent
- Design
- Verification and validation

Key Salient Features Of IPV - Unwanted Thrust

GENERAL

- IPV is a principle not a product
- It can be applied to any system but is a good fit to DP system designs built to the seven pillars
- It is intended to provide superior DP system integrity
- It is intended to be more time efficient than traditional verification methods.
- Data logging
- Confidence indicators

- Robust model based protection
- Shut down prime mover if thruster produces excess thrust or thrust in the wrong direction
- Adherence to the seven pillars (in particular)
  - Autonomy
  - Independence (One per thruster - No commonality)
  - Segregation
  - Differentiation
- Attention to internal and external common cause failures
- Basis of confidence
  - Built to test
  - Test on demand
  - Healthy to operate

CONCLUSION

- UNDUE RELIANCE ON DPO INTERVENTION NOT PRUDENT.
- HIERARCHY OF CONTROLS
  - **Eliminate (Remove the Hazard)**
  - Substitution (Replace the Hazard)
  - Engineering Controls (Isolate People from the Hazard)
  - Administrative Controls (Train People and explain procedures)
  - PPE (Protect the worker)
- WE ARE ACCOUNTABLE!