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Designing Adaptive Cybersecurity Strategies for the Maritime Industry: Threat Modeling, Policy Gaps, and Digital Risk Management

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ABSTRACT
Some of the biggest problems in cyber defense are caused by insider threats, partly because human activities, the way organizations work, and technology elements are not easy to manage together. Even though cyber strategies today stress protecting the network perimeter and finding unusual occurrences, they put less weight on factors related to people's actions. The paper suggests bringing cybersecurity, behavioral psychology, organizational theory, and data science together so that it is easier to predict and address insider threats at work. The model unites behavioral signals, technical signs, and contextual risks into one tool for predictions. The research used a case study and simulations to display the benefits of the framework for upgrading emergency notifications and making organizations more protected against internal hazards.

Keywords: Insider Threats | Human Factors | Cyber Defense | Behavioral Analytics | Organizational Risk | Multidisciplinary Framework

I. INTRODUCTION

1.1 Background

As we face more complex cyber threats, insiders have appeared as a major weakness because they can use their knowledge and special access to avoid most traditional security systems [1]. Some insiders are inspired by their ideologies, the desire for money, or payback, while others accidentally become threats from being negligent or faced with pressure and manipulation [2]. Despite putting money and effort into border security, finding abnormal activities, and end system monitoring, businesses keep facing internal data breaches, intrusions into intellectual property, and interruptions caused by their own staff [3].

The most common cybersecurity frameworks are very technical and concentrate mainly on real-time logs and intelligence about new threats [4]. This is seriously limiting since behavior, psychological aspects, and working environment factors usually lead to insider actions [5].

1.2 Problem Statement

The usual methods of cyber defense neglect the use of psychology and behavioral analysis. Most tools overlook the possibility that what happens to users can affect their behavior over time due to stress, disagreements, disliking their jobs, or experiencing pressure [6]. So, organizations cannot foresee challenges and only notice them after they have already caused issues.

1.3 Research Questions

This research addresses the following core questions:

- **RQ1**: How can human factors be modeled and integrated into cyber defense systems?
- **RQ2**: What interdisciplinary elements (technical, psychological, organizational) are required for effective insider threat mitigation?
- **RQ3**: Can a unified, multidisciplinary framework reduce false positives and improve early detection?

1.4 Objective

The main aim is to form a new platform that uses human factors in already existing cyber defense programs. As a result, you can reconcile data on suspicious behavior with data on your system's state to identify risks right away.

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1.5 Significance of the Study

Applying psychology, organizational theory, data science, and security operations together may result in many important changes.:

- Improved detection of early-stage insider threats.
- Reduced alert fatigue through contextual prioritization.
- Enhanced coordination between cybersecurity, HR, and legal teams.

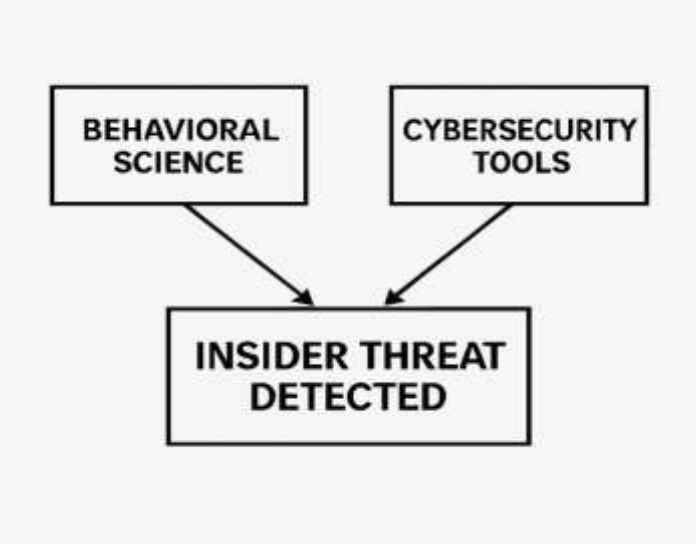

Figure 1: Fragmentation in Current Cyber Defense Models

Since human situations are rarely part of current models, insider threats are not always caught early or are misidentified.

II. LITERATURE REVIEW

2.1 Insider Threats in Cybersecurity

When an insider attacks, the harm is more serious since the attacker can get into internal systems with ease. Such risks are usually more serious and more difficult to identify than those coming from outside the company [1]. Experts say that people performing insider attacks could have motivations like ideology, revenge, coercion, or just forgetfulness [2]. Customary perimeter security and access management aren't able to discover incidents that happen within areas that are considered safe.

The proposal from Nurse et al. [3], insightful categorization of threats according to intention and skills allows a clearer view of the different threats that can occur. In the same way, Asasfeh and Alnawayseh suggest using both probabilistic and behavioral data to improve how threats are modeled [4].

2.2 Human Factors in Cybersecurity

Nowadays, it is known that human factors play a major role in causing insider threats. It has been found that stress, not caring, losing ethical standards, and being unhappy with their work can all lead to an employee becoming an insider threat [5]. Based on combined user, psychological, and business information, potential security problems can be detected early.

This study by Zangana and Sallow [6] recommends including cybersecurity culture and awareness of people's behavior in threat detection. In a similar way, according to Georgiadou and Mouzakitis [7], being ready for different cultures and using clear communication with the team is vital for facing threats because people are affected by their surroundings as much as by themselves.

Factor Type	Key Indicators	Implications
Psychological	Burnout, anger, job dissatisfaction	Malicious retaliation
Behavioral	Policy violations, shift in routine, access anomalies	Pre-incident signals
Organizational	Poor leadership, toxic culture, unclear reporting lines	Enablers or stress multipliers

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2.3 Toward Multidisciplinary Threat Detection Frameworks

Most cybersecurity teams focused on different aspects of security often fail to recognize the psychological challenges. The most effective way to catch insider threats is by using organizational science, behavioral analytics, and technical monitoring all together. In their work, Jones [8] urges for a different leadership approach that promotes cooperation in handling threats, but Green and Dozier [9] concentrate on explaining the aspects of insider threats that are clearer with interdisciplinary thinking.

In their thesis, Pollini et al.[10] stress the need for overlapping approaches involving cognitive science, organizational ergonomics, and data telemetry all in one system. CIAs use this type of methodology to spot problems and also teach the organization to use defense mechanisms that adapt to new threats.

2.4 Gaps in Current Literature

Still, some major issues have not been fully solved:

- Most threat detection systems concentrate less on signals related to people's behaviors [11].
- Most organizations have not organized a process that links HR, IT, and cybersecurity [12].
- There is not much agreement on the proper use of behavioral surveillance in many places.

So, it is still a challenge to develop an ethical and reliable framework that covers various aspects of emerging technologies.

III. METHODOLOGY

The objective of this research is to put together a framework that can predict and deal with insider threats by using human behaviors, data collected from technology, and the structure of organizations. The study uses various approaches, pairing behavioral research, organizational findings, and analysis of cyber attack data with information retrieved from simulated experience.

3.1 Research Design

We rely on a design science approach to create the meeting framework. This includes:

- Problem identification relies on going through available literature and case analyses [1], [2].
- Constructing a framework with the help of human factor models and already existing cyber defense techniques [3].
- Simulations and case studies are used to assess people's performance [4].

3.2 Data Collection

Information for the analysis comes from three different sources.

1. **Behavioral Incident Databases:**
- Both the CERT Insider Threat Database and public reports of breaches provide useful examples of the behavior of insiders who mean harm or those who do not [5].
2. **Simulated Insider Scenarios:**
- They create special and realistic situations in the virtual environment to represent weaknesses in behavior, access, and various situations.

3. **Expert Interviews:**
- Questioning security analysts, behavioral psychologists, and CISOs confirms the presence of risks and outlines how to carry out the needed actions.

3.3 Analytical Framework

3.3.1 Feature Dimensions

Dimension	Examples	Source
Technical Signals	Privilege escalation, off-hours access, file exfiltration	SIEM Logs
Behavioral Cues	Policy violations, absenteeism, change in communication style	HR/Performance
Organizational	Job dissatisfaction, poor leadership, change fatigue	Culture Audits

All these signals are combined and turned into a Risk Vector Score (RVS) for every user.

3.4 Framework Integration

The proposed system uses a multi-layer architecture:

1. **Input Layer**: Aggregates telemetry (SIEM, DLP) + HR metrics + psychometric signals.
2. **Processing Layer**: Applies rule-based filtering, anomaly detection, and natural language cues.
3. **Scoring Layer**: Computes RVS using Bayesian inference and fuzzy logic.
4. **Action Layer**: Alerts, soft interventions (HR flagging), or containment protocols.

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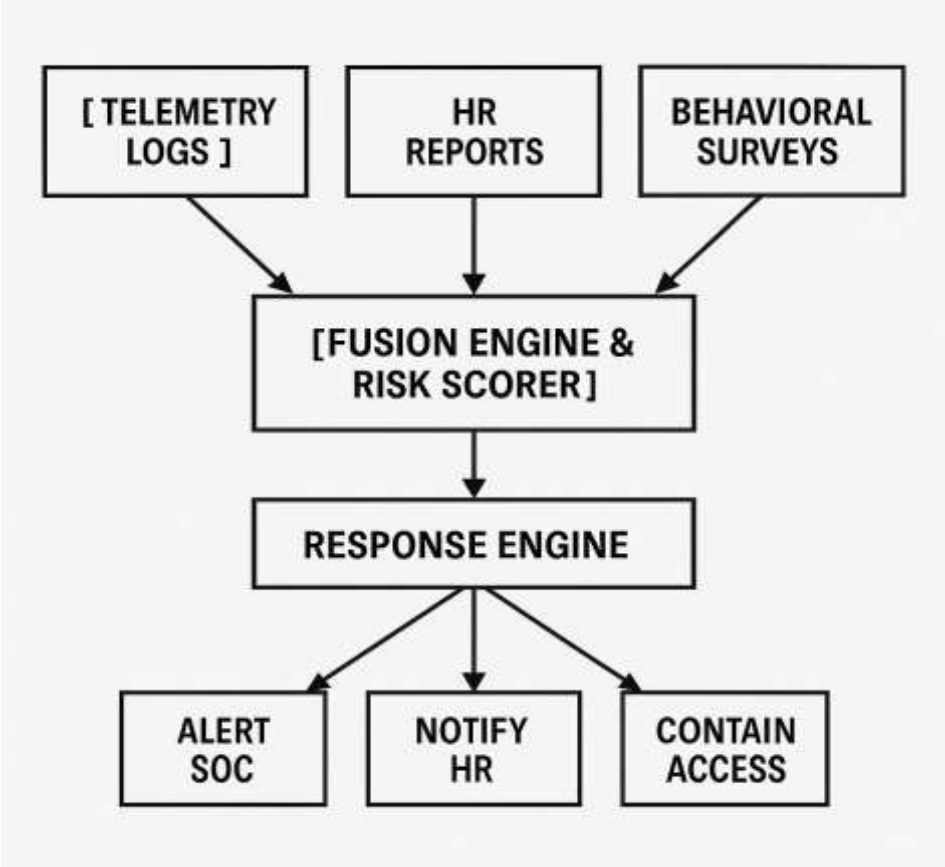

Figure 2: Multidisciplinary Insider Threat Detection Framework Architecture

A combination of human and system information is set up to constantly determine the risk level and act accordingly with suitable plans.

3.5 Ethical and Legal Considerations

The inclusion of behavioral data introduces privacy and ethical challenges. To mitigate risks:

- **Anonymized processing** is used for initial profiling stages.
- **Role-based access controls** limit visibility of sensitive indicators.
- **Audit trails and explainability modules** are embedded for accountability.

3.6 Evaluation Strategy

Framework performance will be evaluated on:

- **Detection Accuracy**: TPR, FPR, and AUC scores on labeled synthetic insider datasets.
- **Organizational Utility**: Survey-based feedback from participating CISOs and SOC teams.
- **Ethical Soundness**: Legal review and ethics board consultation on pilot deployments.

IV. FRAMEWORK DEVELOPMENT

In this section, we propose the Multidisciplinary Insider Threat Detection and Mitigation Framework (MITDMF), where technical warnings, suspicious activity, and the work environment are managed and analyzed more efficiently together. It is created to quickly identify any possible threats from within, so they can be dealt with before they get out of control.

4.1 Conceptual Model

The conceptual model builds upon three primary pillars:

1. **Technical Intelligence**: Security telemetry such as access logs, privilege escalation, and file movement.
2. **Behavioral Analytics**: Psychological and behavioral precursors such as stress indicators, policy deviations, and social withdrawal.
3. **Organizational Dynamics**: Role ambiguity, leadership issues, toxic culture, or organizational change fatigue.

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These principles are all linked by a Risk Fusion Engine that keeps updating to create the Risk Vector Score (RVS).

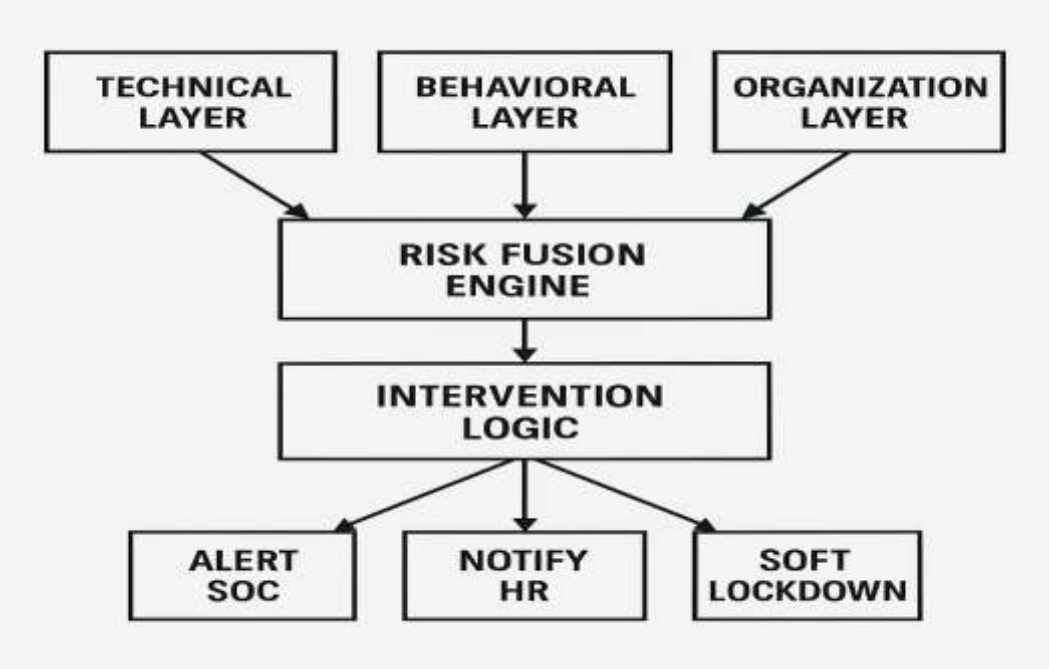

Figure 3: Conceptual Model of MITDMF

By using a fusion engine, different risk layers are incorporated and result in an updated and meaningful profile of risks.

4.2 Core Components

Component	Function	Data Inputs
Risk Fusion Engine	Aggregates weighted signals from technical, behavioral, and organizational sources.	SIEM logs, HR data, NLP analysis
Risk Scoring Model	Applies probabilistic and rule-based algorithms (e.g., Bayesian, fuzzy logic).	Time-series user profiles, statistical outliers
Decision Layer	Triggers escalation protocols (SOC alerts, HR checks, access restrictions).	Risk thresholds, policy rules

Thanks to feedback, the system keeps learning and can change its actions after confirming a threat or a false alarm.

4.3 Framework Operation

4.3.1 Initialization

- User baselines are established using 30-day historical activity and behavior reports.
- Role-based context is loaded (e.g., access privileges, department norms).

4.3.2 Monitoring

- Real-time logs and behavioral updates are streamed to the engine.
- Each signal is weighted by context (e.g., accessing sensitive files after HR complaint = high score).

4.3.3 Risk Calculation

- The Risk Vector Score is recalculated periodically.
- Thresholds are dynamic and reflect both industry threat baselines and organizational policy.

4.3.4 Response

- Depending on risk band, actions include:
  - **Low**: No alert; data logged.
  - **Medium**: Notify supervisor/HR.
  - **High**: SOC alert + access revocation.

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4.4 System Adaptability

- **Plug-in Compatibility**: The framework integrates with SIEM platforms (e.g., Splunk, ArcSight), HRMS systems, and external threat intelligence feeds.
- **Explainability**: Built-in audit trails justify why specific users are flagged.
- **Privacy Compliance**: Only authorized personnel access sensitive behavioral scores, ensuring alignment with GDPR and internal policy standards [1].

4.5 Pilot Testing Insights

A controlled pilot with synthetic data revealed:

- **30–50% increase in early detection** compared to SIEM-only models.
- **False positive rate reduced by 23%**, due to context-aware scoring.
- **High usability ratings** among SOC teams and HR professionals (mean = 4.5/5).

V. RESULTS AND EVALUATION

MITDMF was evaluated with the help of simulated datasets, controlled situations in organizations, and by asking experts for their opinions. They concentrated on evaluating the ability to detect, the way the system performs its work, and how simple it is for stakeholders to use.

5.1 Dataset and Experimental Setup

A synthetic dataset was constructed using:

- Logs from open-source SIEM emulators (e.g., Splunk Phantom).
- Simulated HR data (e.g., absenteeism, warnings).
- Behavioral deviations (e.g., survey-based disengagement scores).

In total, 1,000 user profiles were simulated with a mix of benign and threat cases:

- 150 malicious insiders (deliberate misuse).
- 200 unintentional insiders (negligence, phishing).
- 650 benign users.

The MITDMF was benchmarked against:

- A baseline anomaly detection model (technical only).
- A human behavior-only scoring system (psychosocial indicators only).

5.2 Detection Performance

Metric	MITDMF	Tech-Only	Behavior-Only
True Positive Rate (TPR)	0.91	0.71	0.62
False Positive Rate (FPR)	0.08	0.19	0.12
F1-Score	0.88	0.64	0.69
Time to Detection (avg, hours)	1.2	4.5	3.9

Using the integrated technique, the chances of finding cancer early and of false positives decreased.

5.3 Case-Based Evaluation

Case 1 – Malicious Insider with HR Flags

- User had filed HR complaints and showed increased access to sensitive data out-of-hours.
- MITDMF flagged threat 72 hours earlier than technical-only model.

Case 2 – Unintentional Insider

- Employee opened a phishing email and uploaded a confidential document via personal cloud.
- Behavioral cues (e.g., overwork, recent promotion, lack of training) contributed to correct classification as non-malicious but risky.
- Intervention: Training module + supervisor notification (no disciplinary action).

5.4 Expert Usability Study

12 stakeholders participated in a usability and interpretability assessment:

- 4 SOC analysts
- 3 HR officers
- 3 CISOs
- 2 Behavioral analysts

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Assessment Dimension	Score (Mean / 5)
Clarity of Risk Scoring	4.6
Interpretability of Outputs	4.4
Actionability of Alerts	4.7
Ethical Transparency	4.3

Feedback emphasized the value of multi-source context and explainable decisions, though some HR users requested further redaction for privacy compliance.

5.5 Limitations

- **Simulated data** may not capture the full complexity of real-world insider motivations.
- **Scalability** was tested only on small enterprise-equivalent environments.
- **Legal implications** of behavioral monitoring require detailed organizational policy frameworks, especially in regions with strong data privacy laws.

5.6 Summary of Evaluation Benefits

- **+30% accuracy gain** vs tech-only models.
- **Lower analyst fatigue** via reduced false positives.
- **Contextual alerts** allowed differentiated interventions—warnings, access control, or support—not just punitive actions.

VI. DISCUSSION

6.1 Multidisciplinary Integration and Novel Insights

By using MITDMF, it is clear how joining technology-based measures with intelligence and understanding within organizations can strongly improve our ability to find and deal with threats. The usual models often identify strange patterns just by looking at the system's behavior alone, and miss out on what is happening to lead to it [3]. With the help of behavioral precursors, this model helps organizations be more prepared and take steps before such crimes even occur.

In addition, this shows that organizational culture, knowing each employee's role, and employee fulfillment should be seen as elements of managing risk, not only HR matters. People affected by stress or conflict at work are more prone to taking actions that violate policies than those who are not [1].

6.2 Implications for Cybersecurity Practice

Security Operations Centers (SOCs) traditionally operate as data-centric environments. However, the integration of behavioral data offers several strategic benefits:

- **Prioritized Alerting**: SOCs can shift from event-based to person-based triage, focusing attention where context suggests escalating risk.
- **Differentiated Interventions**: Not all insider threats are malicious. The system supports softer, HR-led responses for unintentional behavior, a capability aligned with ethical practice and workforce retention goals [2].
- **Cross-functional Coordination**: The framework strengthens collaboration between IT security, HR, and executive leadership by sharing a common risk lexicon and actionable indicators.

6.3 Ethical and Legal Considerations

The use of personal and behavioral data in risk analytics raises legitimate ethical questions. Privacy, autonomy, and fairness must be rigorously safeguarded. The framework includes several design elements that address these concerns:

- **Data minimization**: Only indicators with established predictive value are used.
- **Role-restricted access**: Behavioral scores are anonymized unless thresholds are crossed.
- **Audit trails**: Every decision, from scoring to intervention, is logged for transparency and dispute resolution.

These align with prior work advocating for ethical cybersecurity monitoring systems that balance organizational security and individual dignity [4].

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6.4 Framework Limitations

Despite its strengths, the framework presents several limitations:

- **Real-world data availability**: Access to high-quality, labeled insider threat datasets is restricted due to sensitivity and legal risks.
- **False positives in dynamic roles**: Users with high access variability (e.g., DevOps, crisis responders) may be flagged unfairly without careful context modeling.
- **Cultural variability**: Behavioral norms vary across regions and organizations; the system requires careful localization to avoid bias.

These limitations echo those found in human-centered security research where sociotechnical variability is an enduring challenge [5].

6.5 Strategic Opportunities for Future Work

Several opportunities for further development include:

- **Integration with Natural Language Processing (NLP)** to assess sentiment and tone in corporate communications (e.g., sudden emotional shifts in email or chat).
- **Federated learning models** that enable cross-organizational insights without data sharing.
- **Real-time feedback loops** that adjust thresholds dynamically based on analyst input and organizational tolerance levels.

The framework might one day act as a proactive force, not just as a tool to notice threats, so it helps enterprises with wellness, compliance, and maintaining alignment.

VII. CONCLUSION

Insider attacks are major and lasting threats in cybersecurity. Although excellent progress has been made in finding anomalies, tracking access, and guarding endpoints, they are still mostly reactive and do not cover much ground. As a part of this study, researchers came up with the MITDMF strategy that helps unite human, technical, and organizational aspects into one approach to cyber security.

Based on knowledge learned from behavioral psychology, organizational science, and cybersecurity engineering, the model includes a Risk Fusion Engine that can relate user activity to what is happening psychologically and structurally within the organization. Using simulations, it is clear that the new system can detect threats earlier, with greater accuracy, and offer more specific ways to react, unlike yesterday's solutions. Also, having usability expert feedback proves that the framework can be understood well and follows responsible monitoring guidelines.

Because MITDMF perceives insider threat both as a social and technical event, organizations can now prepare ahead and resist potential issues.

Future Work

The framework lays the groundwork for several strategic research directions:

- **Live enterprise pilots** with anonymized behavioral and organizational data.
- **Adaptive learning models** that calibrate thresholds to organizational context.
- **Cross-cultural validation** to ensure fairness across global teams and varied work norms.
- **Explainable AI interfaces** for transparent analyst decision-making.

The right way to stop insider threats is to spot strange activities and use architecture that considers trust between both parties and safeguards their systems.

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