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A systemic analysis of patterns of organizational breakdowns in accidents: A case from Helicopter Emergency Medical Service (HEMS) operations

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ABSTRACT

In recent years, many accident models and techniques have shifted their focus from shortfalls in the actions of practitioners to systemic causes in the organization. Accident investigation techniques (e.g., STAMP) have been developed that looked into the flaws of control processes in the organization. Organizational models have looked into general patterns of breakdown related to structural vulnerabilities and gradual degradation of performance. Although some degree of cross-fertilization has been developed between these two trends, safety analysts are left on their own to integrate this gap between control flaws and patterns of organizational breakdown in accident investigation. This article attempts to elaborate the control dynamics of the *Systems Theoretic Accident Model and Process* (STAMP) technique on the basis of a theoretical model of organizational viability (i.e., the *Viable Systems Model*). The joint STAMP–VSM framework is applied to an accident from a Helicopter Emergency Medical Service (HEMS) organization to help analysts progress from the analysis of control flaws to the underlying patterns of breakdown. The joint framework may help analysts to rethink the safety organization, model new information loops and constraints, look at the adaptation and steering functions of the organization and finally, develop high leverage interventions.

1. Introduction

1.1. Background and objectives

The occasionally but highly consequential failures that have occurred in safety-critical organizations have led to a substantial line of research on how catastrophic failures take place in socio-technical systems and how organizational vulnerabilities are implicated in such failures. Modern accident techniques have shifted their focus from shortfalls in the actions of sharp-end practitioners to the shortfalls in the capacities of organizations to bring about a safe system. In particular, Rasmussen [1] presented a series of models, including the AcciMap technique, that guide analysts to look beyond the immediate events involving individual operators and examine management factors that created the pre-conditions for accidents. Similarly, Leveson [2] developed the *Systems Theoretic Accident Model and Process* (STAMP) technique that focuses on the control processes and constraints between different levels in the safety management system. Systemic accident models have been particularly useful in helping analysts probe into the complicated interactions between system components that may lead to performance decrements and unfortunate events.

At the same time, other researchers have relied on organizational models to reveal organizational vulnerabilities and degradation phenomena that generate flaws in the control processes or the enforcement of constraints (see synoptic review in [3]). Perrow's 'normal accidents' model [4], for instance, has been extensively used to look into aspects of interactive complexity and tight coupling in the structure of organizations that make accidents virtually inevitable. Beer's Viable System Model [5] has been applied in accident investigation [6,7] to reveal problems in the way that organizations structure their operations and manage their 'requisite variety' to respond to adverse events in the environment. The literature that deals with degradation has arisen with the observation that it takes time before vulnerabilities escape the capabilities of organizations to deal with them. Turner's model of 'incubation' [8] has pointed to the gradual progression towards a failure that is not seen and the discounting of signals of an incipient disaster. This degradation has also been linked to the gradual built-up of latent failures and organizational omissions [9,10], the erosion of protective forms of slack [11], the drift of local practices from the overall plan [1] and the reinforcing loops [12] that move such practices further from the normative forms. These patterns of breakdown deserve further

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attention since they tend to repeat themselves in many industries, underlying the shortfalls in the actions of practitioners.

These two trends in the development of organizational models and techniques for accident investigation have been taken place in parallel, with some degree of cross-fertilization. Although both AcciMap and STAMP techniques take a systems perspective, they remain rather neutral with regard to specific models of organizational structures and processes. This increases the gap between organizational models and techniques of investigation, hence leaving practitioners and analysts on their own to integrate the vast literature of organizational breakdowns and apply it to their specific domain. The purpose of this article is to elaborate the control dynamics of STAMP on the basis of a theoretical model of organizational viability. In particular, the Viable System Model (VSM) seems to suit this objective as it has already been applied in several cases of accident analysis [6,7,13,14]. The Viable System Model (VSM, [15]) has been adapted to a certain degree to fit the progression from control flaws (in STAMP) to patterns of breakdown especially at the organizational and regulatory levels. To illustrate this link between STAMP and VSM, a case study was used from Helicopter Emergency Medical Services (HEMS).

This article is structured as follows. The remainder of Section 1 looks at the context of work of HEMS operations worldwide and presents three accidents that occurred in Greece. Section 2 presents a theoretical framework that integrates the STAMP analysis with the Viable System Model so that new categories of analysis are introduced. To illustrate the advances of the proposed framework, the STAMP technique is applied to the analysis of control flaws of the first HEMS accident in Section 3. Subsequently, the Viable System Model is applied (Section 4) to reveal the organizational breakdowns underlying the flaws of control algorithms identified with STAMP. Section 5 concludes this article with a discussion on the proposed framework.

1.2. The context of HEMS operations worldwide

Helicopter Emergency Medical Service (HEMS) organizations undertake a wide variety of operations throughout the world. A fleet of suitably equipped helicopters is dispersed strategically in the areas of interest, taking into account equipment and hospital availability. An Operational Control Center (OCC) is established in the capital city and is complemented with a number of command posts at carefully chosen 'forward bases'. The OCC provides flight dispatches, supports crews in conducting flight assignments and coordinates with Air Traffic Control (ATC) for the safe and expeditious transfer of patients to the final destination. Helicopter crews, ATC controllers and OCC dispatchers are tasked with complex decisions such as sizing-up an escalating situation, utilizing information from multiple sources and balancing goal conflicts [15]. Time parameters are quite strict. Information uncertainty may trigger replanning of a flight while unforeseen delays may trigger route changes and rule adjustments in conducting the flight. For example, a Visual Flight Rules (VFR) flight expected to terminate before the sunset may be changed into a night VFR or an Instrument Flight Rules (IFR) flight in the darkness, which increases operational demands. Weather conditions may be deteriorating faster than expected, hence giving rise to trade-offs between direct routing through adverse weather and indirect routings around the danger area. Eventually the pressing need to use ill-equipped aerodromes, or even search for a suitable ground area for landing at night, usually adds to the complexity of operations. Flight crews, air traffic controllers and OCC personnel set the boundaries of an ad-hoc Joint Cognitive System, which is characterized by patterns of resilience, coordination and affordances [16].

The growth of HEMS industry was significant over the last two decades. Although it was perceived as safe sector of aviation, the number of HEMS accidents has alarmingly increased over the last years. In the US, a number of 85 HEMS accidents resulted in 77 fatalities in the period from 2003 to 2008. Inevitably, HEMS operations were brought into the attention of U.S. Government, the National Transportation Safety Board [17], the Federal Aviation Administration (FAA) and the aviation industry. FAA conducted a thorough analysis of HEMS accidents and identified three primary safety concerns: inadvertent encounters of Instrument Meteorological Conditions (IMC), night-time VFR flights and Controlled Flight Into Terrain (CFIT) cases. Similarly in Europe, HEMS operations were identified as the riskiest sector of aviation with a poor safety trend, which is complicated by a recognized inability to obtain valuable data and classify accurately their causes [18].

1.3. A description of HEMS accidents

Following aviation deregulation (summer of 2000), HEMS operations were nominated to HELITALIA, an Italian company that would conduct emergency medical services operations in the Aegean islands of Greece. Primary oversight of HEMS flights was formally assigned to ENAC, the Italian Civil Aviation Authority, with the Hellenic Civil Aviation Authority (HCAA) assuming an additional layer of control. After only six months of operations, the first accident occurred on January 14th 2001, in adverse weather conditions resulting in 5 fatalities. The flight departed from Athens to the island of Patmos in relative good conditions and a meteorological forecast of rapidly deteriorating weather from the west. During the return flight, the helicopter entered a storm cell near Athens aerodrome. Although it was night and the weather was bad (calling for Instrument Meteorological Conditions), the helicopter adopted a VFR flight. It crashed into the sea, a few miles away from Athens aerodrome. The continuation of the VFR flight into IMC conditions and the failure of the crew to recognize the adverse weather were cited as the most important causes of the crash [19].

The second accident occurred 15 months later (June 16th, 2002) with 5 fatalities. The helicopter crashed into a mountain during its initial climb phase, after departing from a heliport in Anafi, a small island near Santorini. Once again, the helicopter was flying VFR at night. The decision of the crew to take a shortcut by flying over mountainous terrain – rather than using the published departure procedure – was identified as the most critical of cause of the second incident [20]. Eight months later (February 11th, 2003) a third accident occurred in the vicinity of Ikaria aerodrome where a helicopter crashed into the sea while flying VFR at night during the final stages of the approach for landing [21]. Although the evidence was inconclusive, the investigation committee claimed that the cause of this incident was a major electrical failure encountered suddenly at the final stages of the approach, which was not diagnosed correctly. A few days later, the HEMS company ceased its operations under nationwide criticism for misconduct of operations.

All three investigations were conducted by an independent accident investigation board, using the guiding principles of ICAO. However, all investigations were severely affected by the absence of data from Cockpit Voice Recorders (CVRs) and Flight Data Recorders (FDRs) since no regulatory requirements existed worldwide for having such systems in helicopters. This very fact prolonged the investigations and led to many assumptions about the real causes of the accidents, relying only on ATC information (voice transcripts between ATC and the flight crew and also ATC radar data) since the electronic footprint of the three flights was minimal. Apparently, the investigation reports failed to provide any preventive function. On the contrary, they were used for legal cases against the organizations involved. Furthermore, many