Analyzing Helicopter Emergency Medical Services Accidents using STAMP

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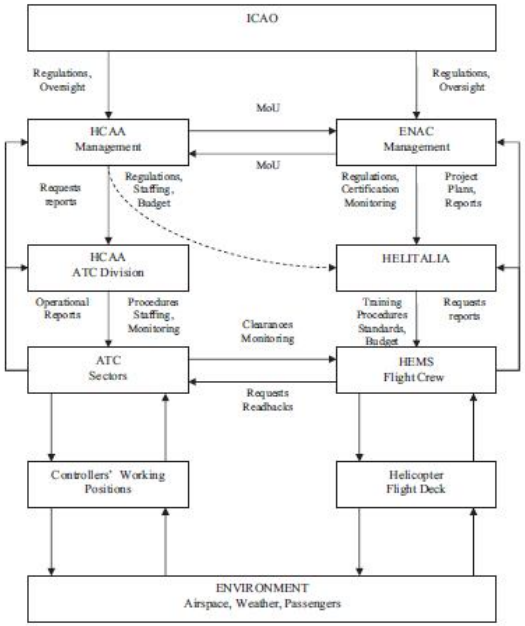
The Structure of the Presentation

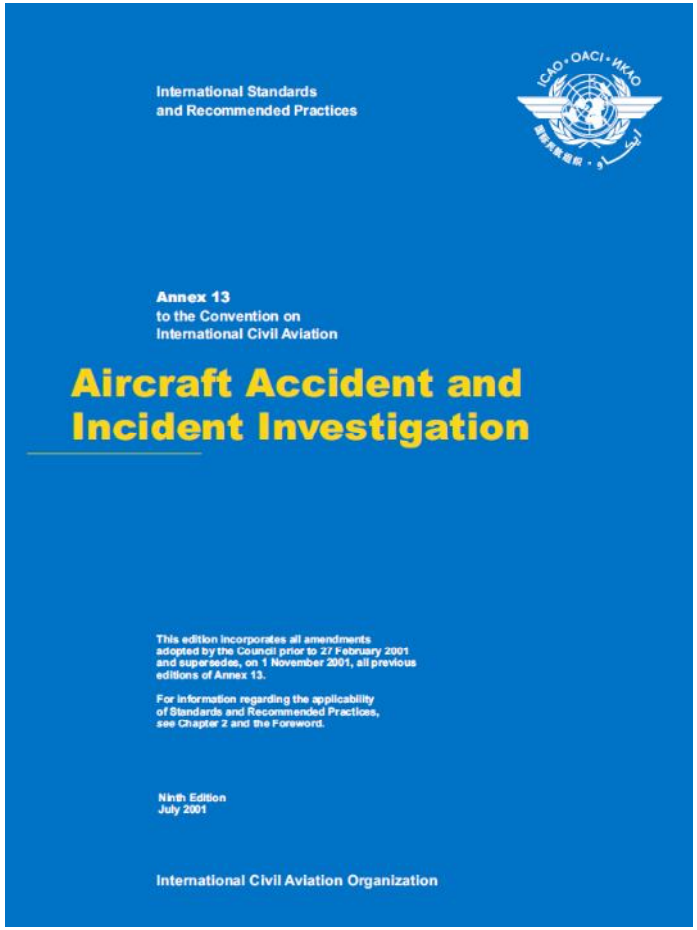
1. The origins
2. STAMP Analysis
3. Conclusions



Two dimensions of Questions

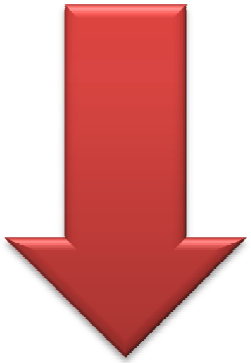
1. **Professional : (As an Air Traffic Controller)**
   - ❑ What can we really learn from these accidents?
   - ❑ Is the ICAO procedure adequate for these type of accidents?
2. **Research : (As an HF Researcher)**
   - ❑ Can we apply STAMP in a series of accidents?
   - ❑ What are the difficulties in applying STAMP?

ICAO MANDATES



"… the sole objective of an investigation is the prevention of similar accidents".
(*ICAO - ANNEX 13 : Aircraft Accident and Incident Investigation, 2001*).

BUT!!!



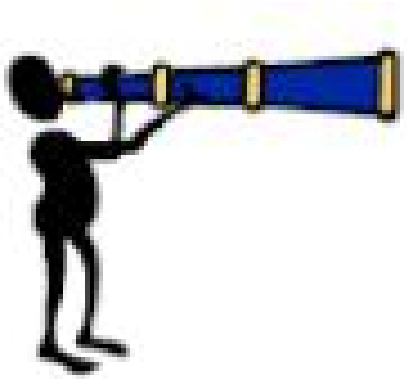
Do we really prevent a similar accident ???

The Fundamental Assumption

After an accident **sufficient time** is provided to ***complete*** the investigation process, ***formulate*** the lessons-to-be learned, ***disseminate*** information to the interested stakeholders and ***allow*** the industry to ***incorporate*** them preventing an analogous accident.

ICAO's Guiding Principles

- Technical failures and human errors could be traced back into discernible 'latent' failures in the organization.
- The most important aim of the accident investigation process is to plot the accident trajectory by providing a comprehensive list of 'defences-in-depth' that failed.
- The analysis represents the culmination of two industry-wide beliefs.
  1. A **thorough examination** of the accident was performed and,
  2. A **deeper understanding** as to what really happened and most importantly what went wrong was obtained.



Helicopter Emergency Medical Services (HEMS) Operational Concept

- HEMS are founded on the inherent ability of the helicopters to land and take-off practical anywhere.
- The concept of operation of EMS organizations is quite simple.
  - A fleet of suitably equipped helicopters is dispersed strategically in the area of interest based on their range and hospital availability.
  - An Operational Control Centre, (OCC) is established normally at the capital city, with the widest array of medical services, complemented with a number of command posts at carefully chosen forward bases.
  - The OCC provides flight dispatching and aids the crews in accepting, planning and conducting a flight assignment.
  - The acceptance of a mission signifies the initiations of operations at three interconnected levels.
    - **Flight Crew** flies the helicopter to the area from which the patient can be picked and then flies her/him to the final destination.
    - **ATC units** provide separations with other aircraft and surrounding terrain and also flight information services (e.g. weather information, information regarding operational status of terminal and en-route navigation aids).
    - **OCC** monitors the overall mission progress and coordinates with the ATC and the medical organizations for the safe and expeditious transfer of the patient to the final destination

Understanding Risk in HEMS operations

- The growth of the HEMS industry was significant over the last two decades.
- It was considered as a relatively safe segment of aviation operations and the risk was low as the best of machines and personnel was assigned.
- In the United States of America from 2003 until 2008, a number of 85 HEMS accidents resulted in 77 fatalities.
- The year 2008 was the deadliest year for HEMS operations with 8 fatal accidents and 29 fatalities, as compared to two fatal accidents and 7 fatalities in 2007.
- FAA conducted a thorough analysis of HEMS accidents and identified three primary safety concerns:
  - Inadvertent Instrument Meteorological Conditions (IMC) encounters,
  - Night operations, and
  - Controlled Flight Into Terrain (CFIT).
- In the European continent, a similar situation exists as HEMS operations were identified as one of the most risky segments of the aviation operations with an adverse safety trend which is complicated by a recognized inability to obtain valuable data and classify accurately their causes (EASA, 2009).
- Large scale safety initiatives were triggered in USA and Europe with the aim of reducing the rate of HEMS related accidents.

The Greece Case

- **Islands:** The need for flights to and from islands in order to pick-up patients and transfer them into mainland hospitals where medical services are superior.
- **Climate- WX:** The combination of three different climates in a relative restrictive area and the uneven terrain give rise to severe weather patterns with gusting winds and thunderstorms. These adverse weather patterns are sweeping Greece from the west and proceeding progressively to the east.
- **Safety Oversight:** Safety oversight during the start of the previous decade was in its very infancy as Hellenic Civil Aviation Authority, (HCAA) was initiating its first Safety Management System program and domain experience was limited to a team of low and middle level personnel with restricted authority.
- **Diverted Attention :** The HCAA was in the midst of a major operational transition from procedural ATC services to Radar services due to a recent fatal aviation accident and in parallel the on-going complicated and time-pressured relocation process of the Athens aerodrome due to the forthcoming Olympic games.
- **Medical Facilities :** Medical facilities at small Aegean islands are elementary and the personnel is young and inexperienced.
- **Decisions for Medical Transfers :** Decisions for an emergency medical transfer was often the only valid decision for even minor cases in order to avoid blame and a quite certain court case for malpractice in case of an adverse outcome.

Serendipity

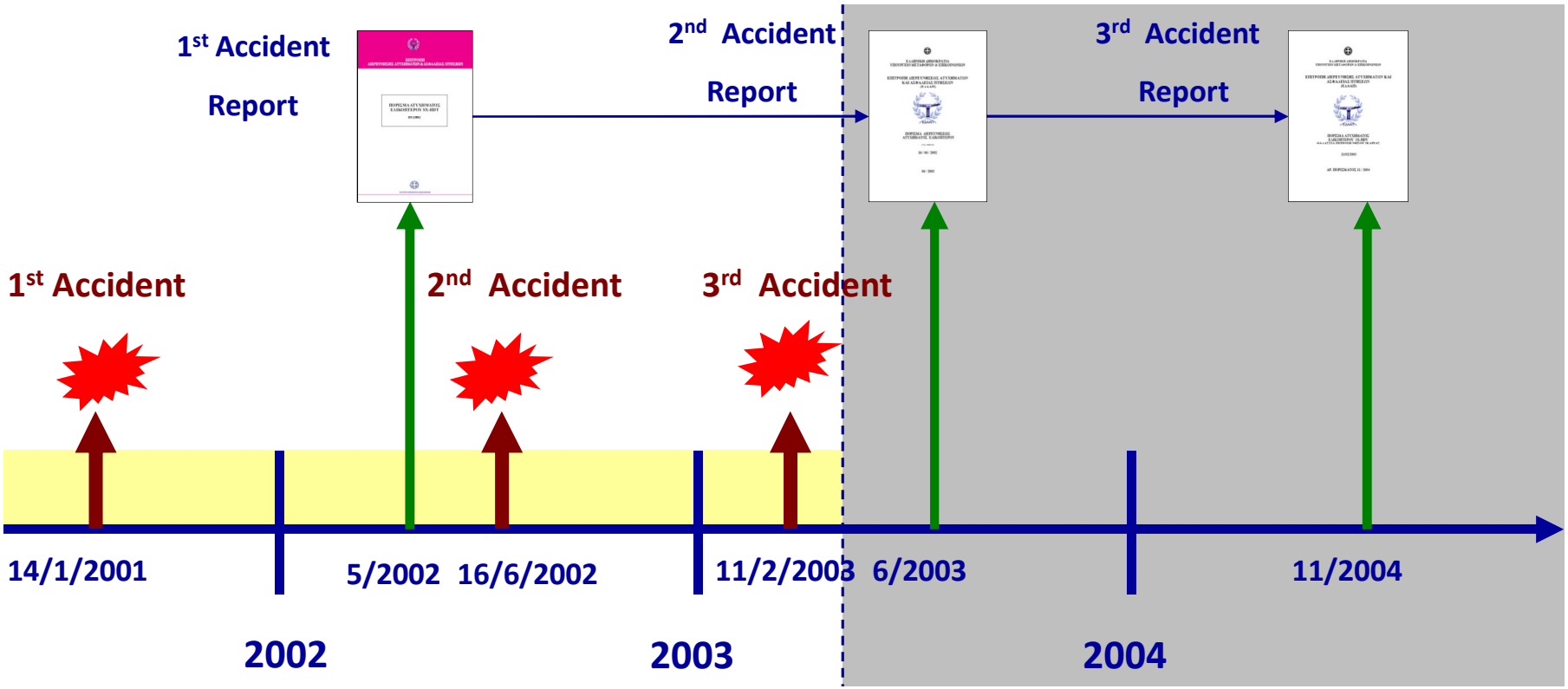
- **The making of happy and unexpected discoveries by accident or when looking for something else, such as discovery.**
- Until 2000, EMS operations in Greece were conducted by a combination of airplanes and helicopters of the Hellenic Army, Navy and Air force in close cooperation with the flag carrier Olympic Aviation.
- Contrary to what was expected the concept of operation was quite successful with an increased level of safety and an in-built operational agility.
- Its success can be traced into three factors.
  - **Resources :** A wide range of helicopters, airplanes and even warships were available for EMS operations.
  - **Expertise :** Civil and military flight crews were largely familiar with the terrain and unique weather patterns in the Aegean Archipelago as they were flying every day in the same routes and encountering the very same weather phenomena.
  - **Flag Carrier :** A set of frequent connections between the islands and Athens by the Olympic Airways accommodated a lot of EMS requests with a minimal disruption of the operations. Olympic airways, was tasked with having an airplane on readiness in Athens during nigh time to conduct EMS flights to the islands as well as accommodating urgent requests with scheduled flights or even diverting airplanes during day time.

A tale of three accidents

- The first accident happened on January 14th 2001, in adverse weather conditions with 5 victims.
  - The flight departed from Athens to the island of Patmos in relative good conditions and a meteorological forecast of rapidly deteriorating conditions from the west.
  - During the return flight it actually entered a storm cell near the aerodrome of Athens.
  - The helicopter was flying following Visual Flight Rules during night, in Instrument Meteorological Conditions and in adverse weather conditions.
  - It crashed into the sea south 7 Nm from Sounio cape near Athens aerodrome.
  - Continuing its flight into adverse weather conditions was cited as the most important of the set of probable causes of the crash (AAIASB, 2002).
- The second accident happened 15 months later with 5 victims.
  - The flight crashed during the initial climb phase after the departure from a heliport in the small island of Anafi, near Santorini.
  - Once again the helicopter was flying following Visual Flight Rules during night when it crashed in a nearby mountain.
  - The decision of the flight crew to take a shortcut by flying over mountainous terrain and not using the published departure procedure was identified as the most critical of the causes.
- Eight months later the third accident happened with 4 victims in the vicinity of Ikaria aerodrome.
  - The flight was crashed into the sea only 1.2 nautical miles east of aerodrome while it was flying once again following Visual Flight Rules during night.
  - The encounter of a sudden major electrical failure that the flight crew mismanaged during the final stages of the approach was cited as the probable cause although inconclusive evidence existed (AAIASB, 2004)..
  - A few days after the third accident the EMS company ceased operations under heavy media attack and nation-wide criticism for misconduct of the operations. i

Analyzing a Counterexample

- **The patterns of the accidents and their investigation processes provide a strong counterexample for the time sufficiency and the informative segment assumptions.**
  - Investigation of the first accident was completed when the second accident happened and reports for the second and third accident were published long after the organization had ceased operations.
  - The alarming trend of increased HEMS accidents worldwide was largely undetected until recently as formal regulatory-compliant data collection methods 'muted' the elicitation of informative patterns.

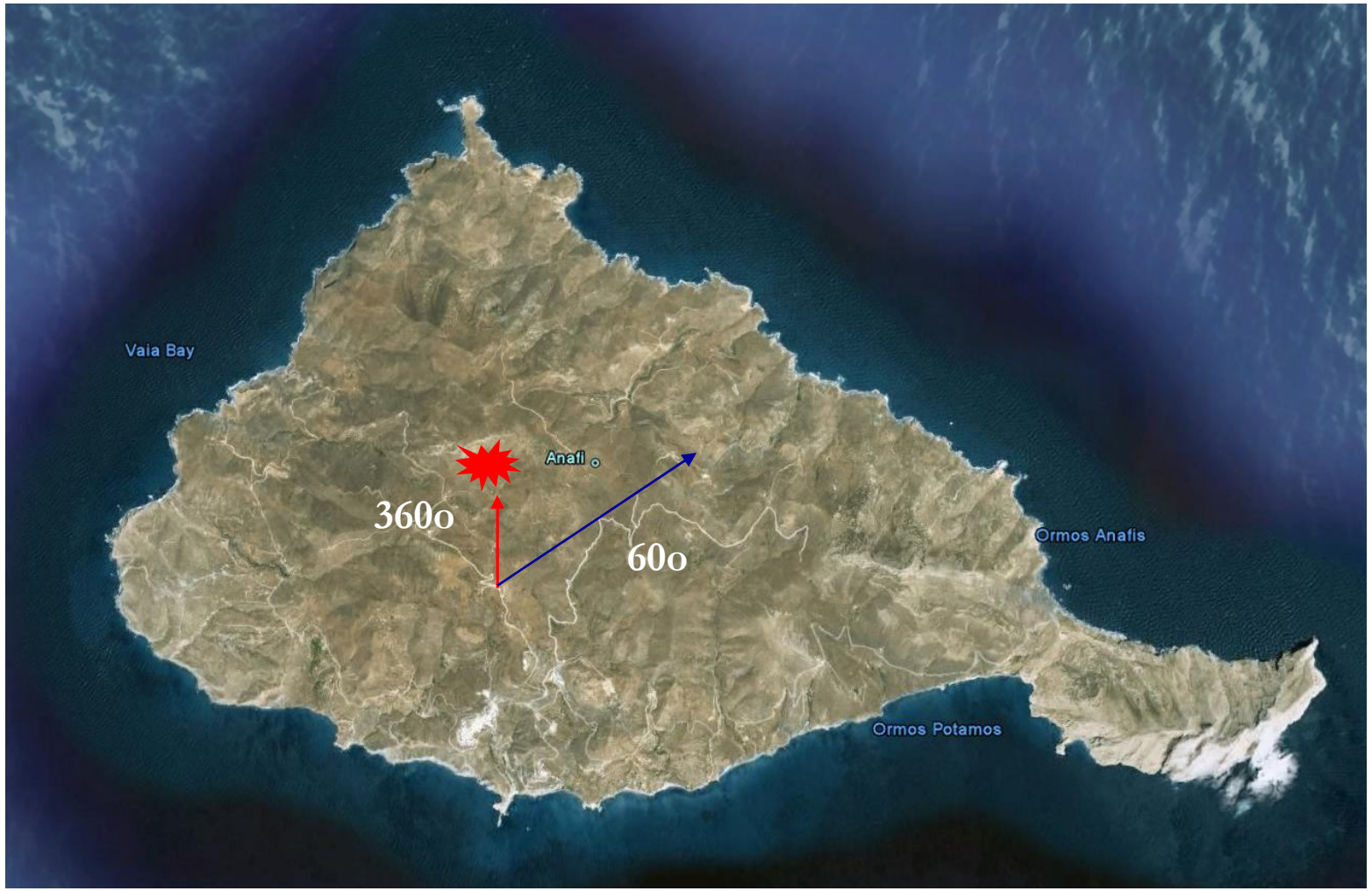


The First Accident

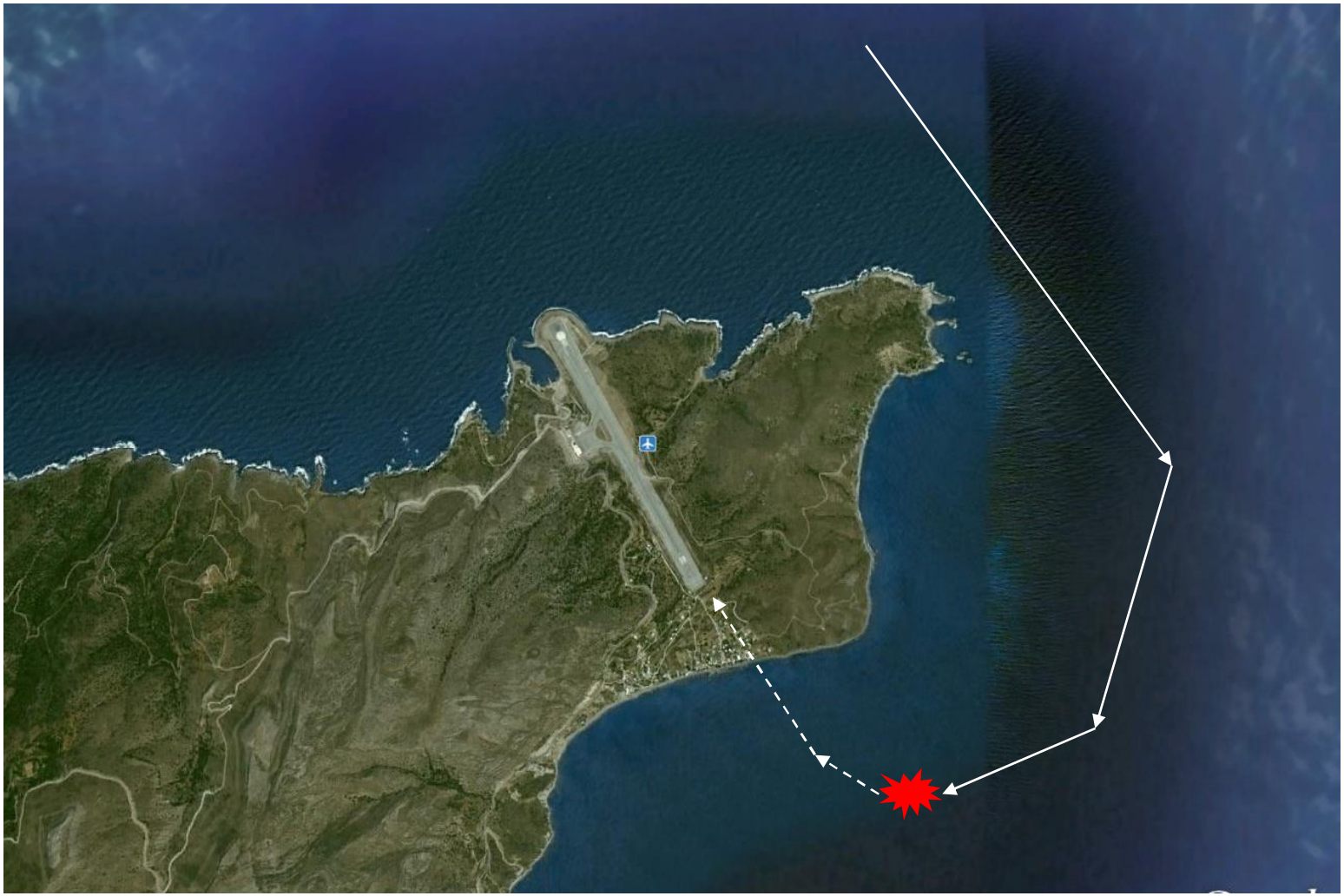
The Second Accident

Actual Course

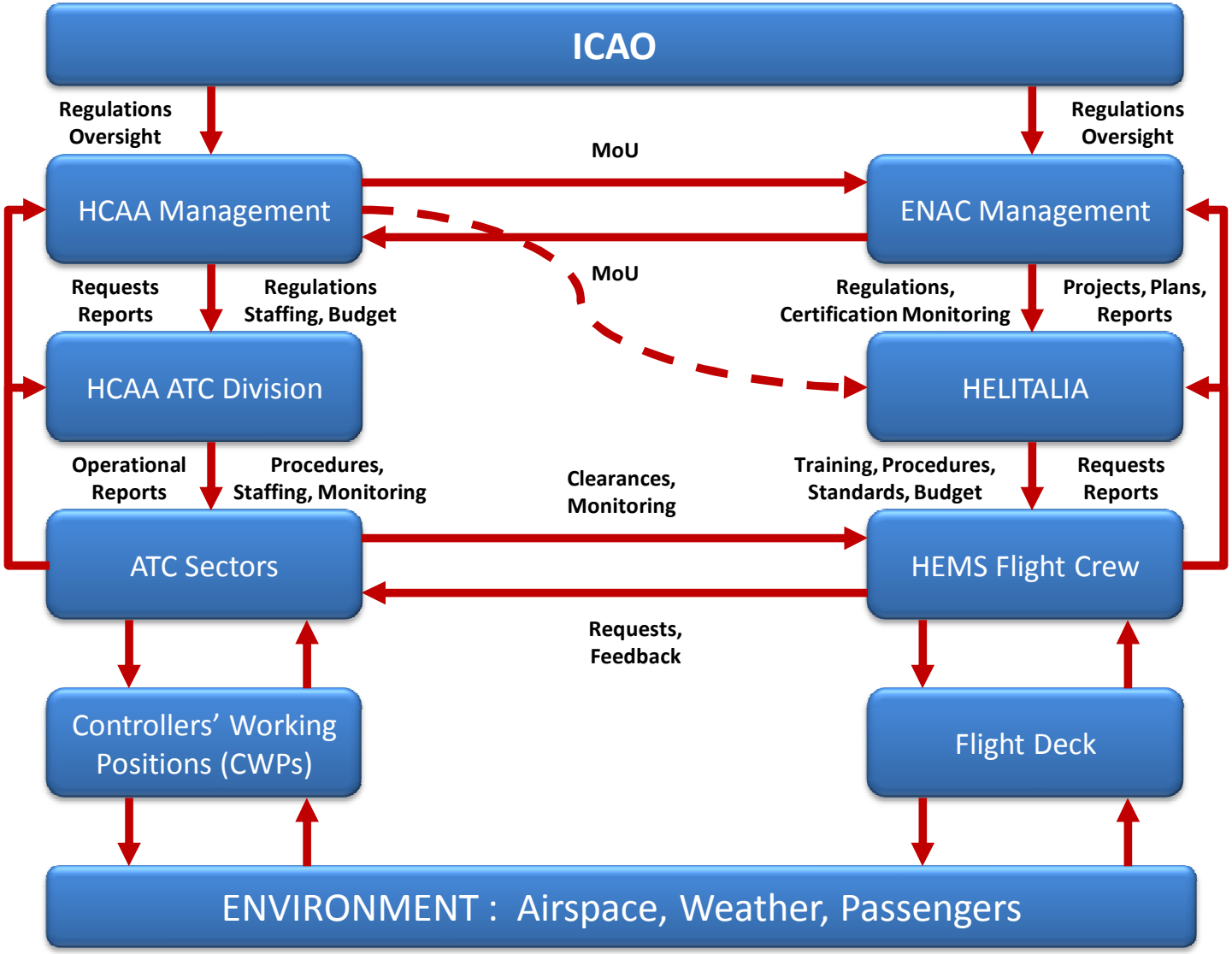
Prescribed Course



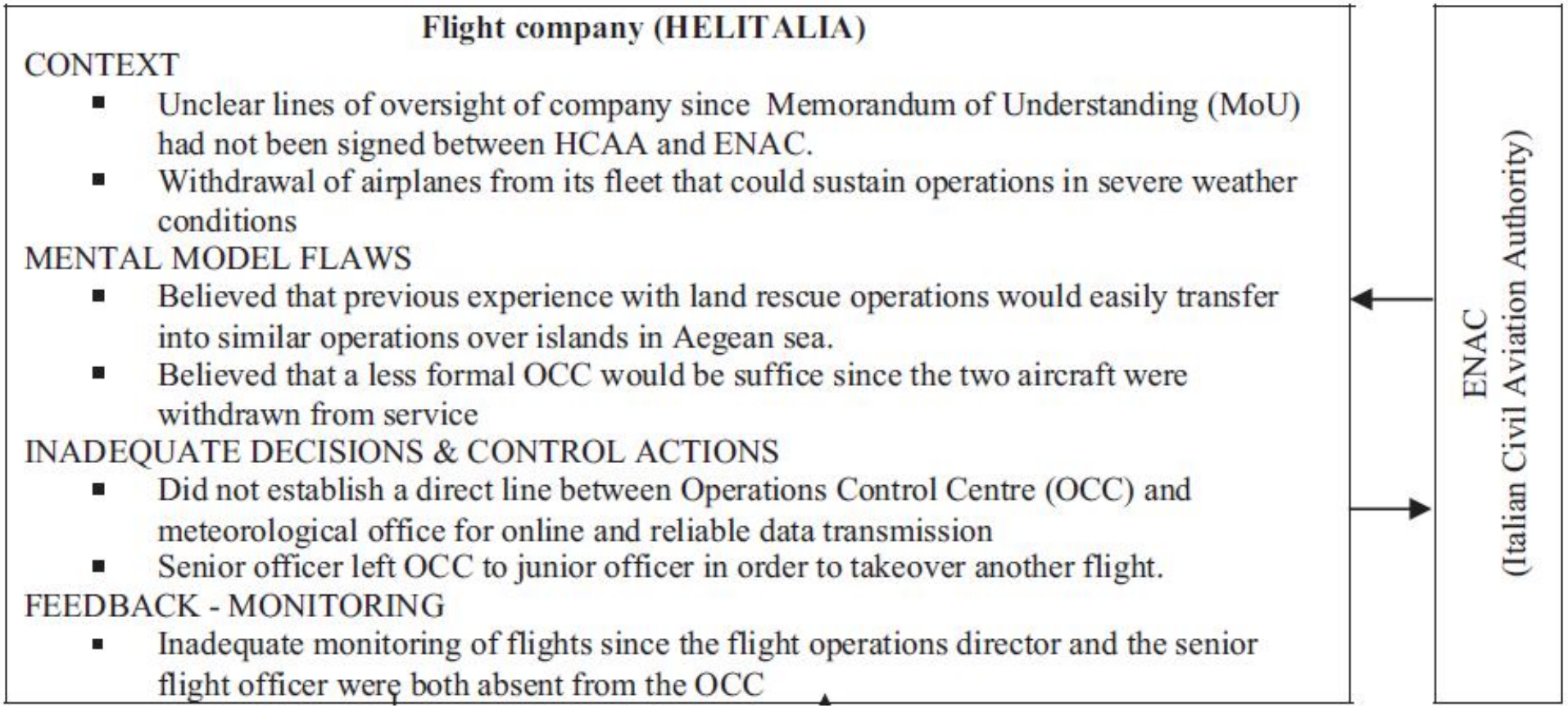
The Third Accident



The Control Structure



Control Flaws - I



Control Flaws - II

HEMS crew

CONTEXT

- Captain was also the flight operations director, sharing flights with several administration responsibilities
- Main experience was with rescue operations in automobile accidents over mainland
- Language barrier between captain and the co-pilot

MENTAL MODEL FLAWS

- Had a poor mental model of gusting winds and severe weather patterns over Aegean
- Inadequate experience in IFR flights at night

INADEQUATE DECISIONS & CONTROL ACTIONS

- Continued VFR flight into Instrument Meteorological Conditions (IMC)
- Insisted on proceeding to final destination instead of diverting to an alternative airport

COORDINATION

- Crew expected the approach controller to alert them when to abort continuation of flight and vector aircraft to alternative airport

Control Flaws - III

Air Traffic Control

CONTEXT

- Several commercial aircraft waited on holding patterns due to severe weather
- VFR position was transferring operations to IFR position
- Flight conditions were deteriorating due to severe weather and gusting winds
- Radio communications with HEMS crews flying low attitude were impeded

MENTAL MODEL FLAWS

- Believed that commercial flights in holding patterns should be given priority and underestimated the risk of HEMS flights

INADEQUATE DECISIONS & CONTROL ACTIONS

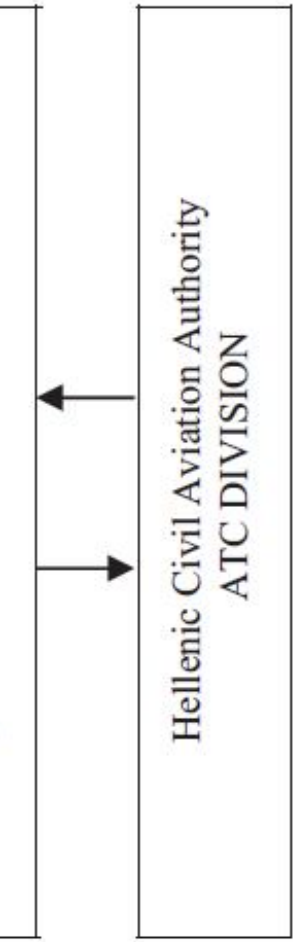
- Controller at Mykonos airport gave crew an outdated meteorological bulletin
- IFR controller did not update transponder code for HEMS flight which caused delays in identifying this flight on radar screen

FEEDBACK - MONITORING

- Approach controller did not provide crew with detailed weather update
- Approach controller did not give priority to the HEMS or sanitary flight over others as required in regulations for weather deteriorating conditions

COORDINATION

- Several ATC sectors were involved in traffic communications without managing an adequate coordination with HEMS crew



Control Flaws - IV

Regulatory authority (HCAA)

CONTEXT

- HCAA was in the midst of a major transition from procedural to radar services
- A relocation of the Athens aerodrome drained nearly most HCAA recourses.
- Other high profile projects were running in parallel for the Olympic games

MENTAL MODEL FLAWS

- Believed that new HEMS organization will be as successful as the previous one
- Poor perception of risks and problems involved in HEMS flights

INADEQUATE DECISIONS & CONTROL ACTIONS

- Did not prepare safety assessments of newly built heliports in Aegean islands
- Did not evaluate operations at the control centre of HELITALIA

COORDINATION

- HCAA did not coordinate with ENAC to sign Letter of Memorandum

Discovering Patterns

- **Regulator oversight of previously successful models of operation.** Regulators are frequently saturated by the demands of methodical oversight of a wide range.
- **General experience and night Visual Flight Rules (VFR) operations.** Night VFR is an acceptable and regularly compliant form of operation all over the world and plainly endorsed by ICAO. The concept is not intended for revenue flights but rather aims to fill-in gaps by acknowledging social needs in the form of EMS and Search and Rescue operations at night.
- **Mixed airplane and helicopters operations and adverse weather circumnavigation**. The initial decision for a mixed fleet of helicopters and airplanes was degenerated into a helicopter-only fleet due to inadequate requirements specifications.
- **Operations in uneven terrain and visual shortcuts.** Most of the aerodromes and heliports in the Aegean islands are surrounded by elevated terrain. Instrument flying departure and approach procedures aimed at protecting aircrafts from the obstacles are lengthy and time consuming for a full scale execution. Responding to this tactical complexity most of the flight crews have developed simple heuristics to follow shortcuts close to the elevated terrain when in VMC in order to avoid time delays and fuel consumption.
- **Degraded systems in dispersed mode operations.** Achieving an increased level of helicopter operational readiness in a dispersed operation mode is placing heavy demands into the maintenance processes. Having a helicopter on 20 minutes readiness in day time and 30 minutes during night in a forward base poses great demands in the maintenance operations and "slight" deviations from the procedures may be tolerated locally.

Initial Questions Revisited

1. **Professional : (As an Air Traffic Controller)**
   - ❑ What can we really learn from these accidents?

   A lot more can be gained by applying STAMP.
   - ❑ Is the ICAO procedure adequate for these type of accidents?

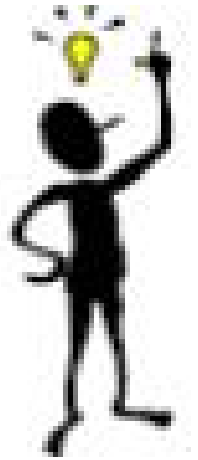
   No, it needs revision.
2. **Research : (As a Researcher)**
   - ❑ Can we apply STAMP in a series of accidents?

   Yes, with stable results.
   - ❑ What are the difficulties in applying STAMP?

   Domain expertise and a level of familiarity with control engineering is needed.

Steps Ahead

1. **Working on integrating a Team Decision Making Model at the low level.**
   - ❑ A recently developed Team decision making is applied keeping in line with control flaws.
   - ❑ Initial results looks promising.
2. **Combining STAMP with other Accident Models to get a better picture.**
   - ❑ VSM model has been applied in parallel in order to enhance results.
   - ❑ Total picture of the accident trajectory has been improved.



Further Information

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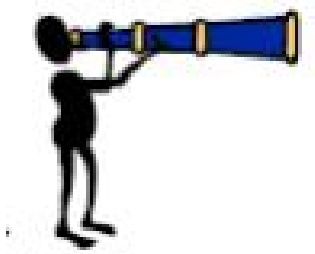
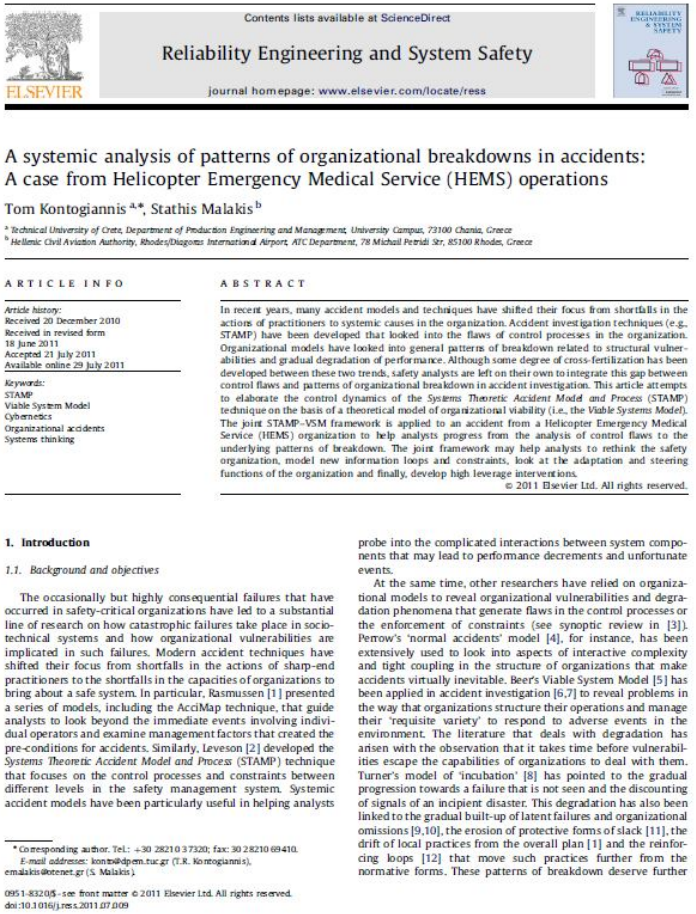
Kontogiannis, T. & Malakis, S. (2011). **A Systemic Analysis of Patterns of Organizational Breakdowns in Accidents: A Case from Helicopter Emergency Medical Service (HEMS) Operations.** Reliability Engineering & System Safety, doi.org/10.1016/j.ress.2011.07.009.





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Reliability Engineering and System Safety

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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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ARTICLE INFO

Article history:
Received 20 December 2010
Received in revised form
18 June 2011
Accepted 21 July 2011
Available online 29 July 2011

Keywords:
STAMP
Viable System Model
Cybernetics
Organizational accidents
Systems thinking

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.

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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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doi:10.1016/j.ress.2011.07.009

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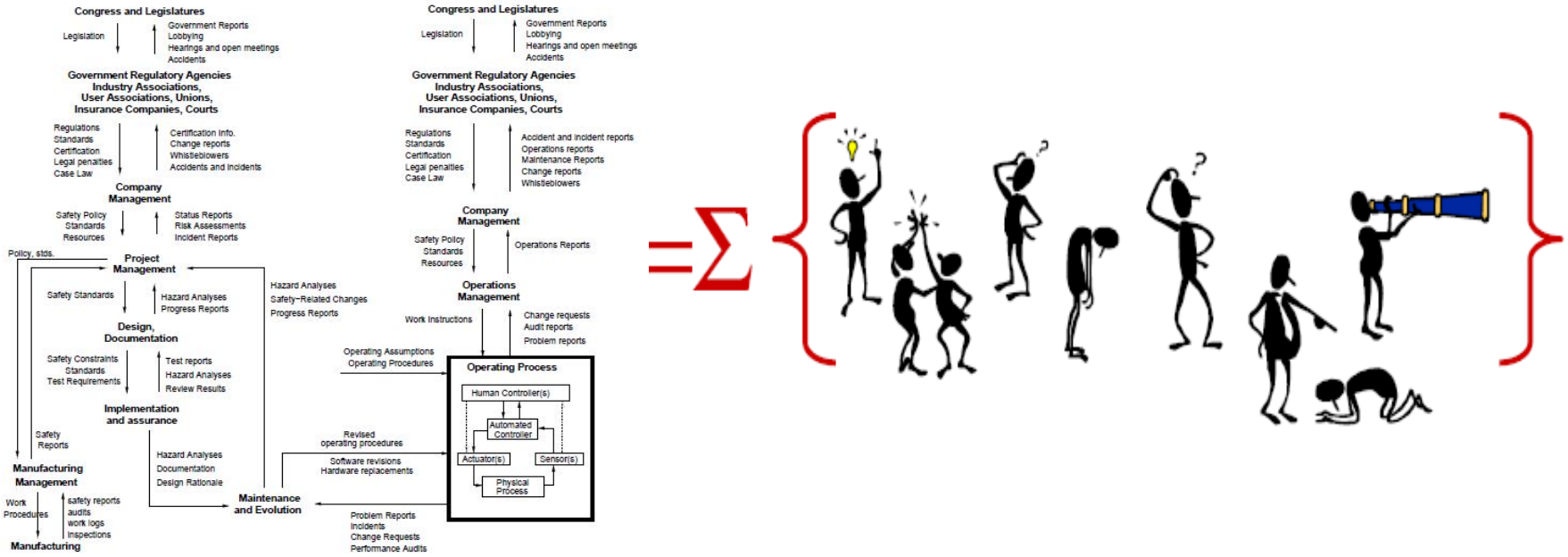

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